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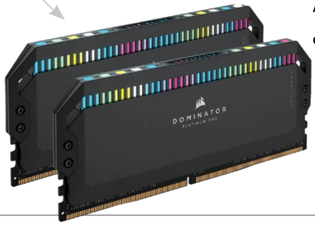

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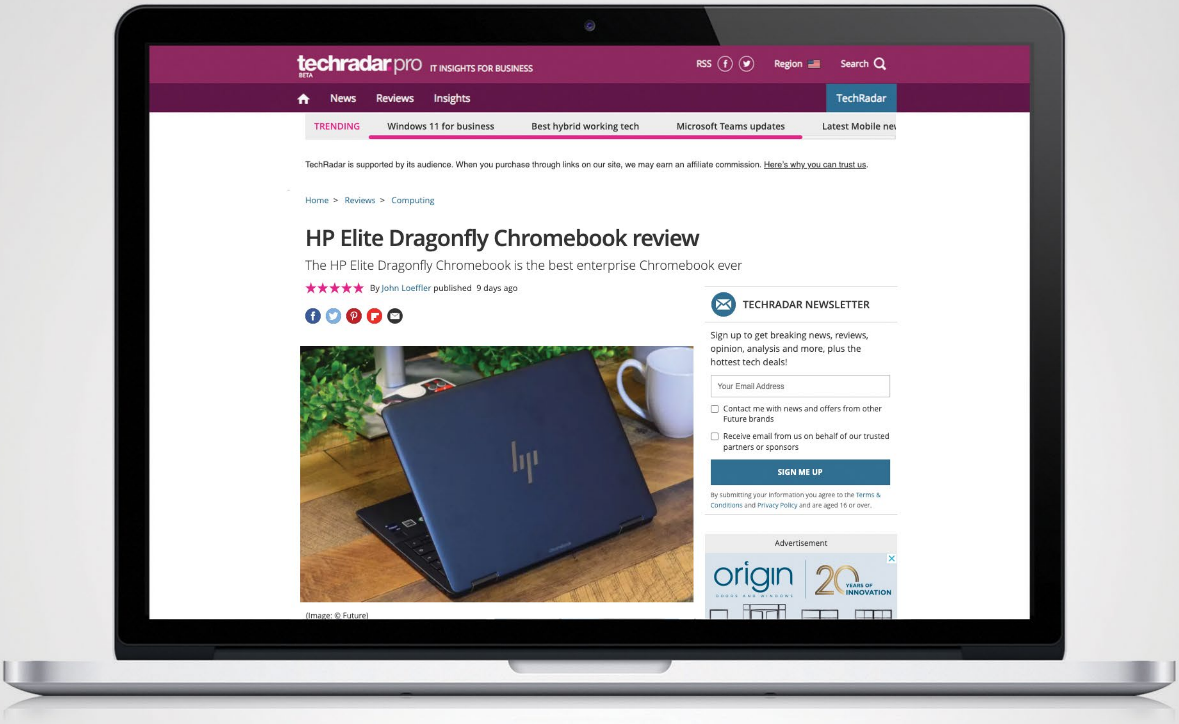

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★★★★★ By John Loeffler published 9 days ago

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Guy
Cocker

‘CLOCKING CRAZY

I'M SURE IT hasn't escaped your attention, but the cost of living is going up. Gas prices are higher than ever, inflation is running away from pay rises, and many expect us to be in a recession by... well, by the time you've finished reading this sentence.

However, in the computing world at least, prices in some areas are coming down, such as graphics cards, SSDs, and DDR 5 RAM. But then again, prices were so artificially high during the pandemic that it's less of a discount and more of a return to where they should have been in the first place.

With that in mind, in this month's cover feature we look at how to put together a solid mid-range PC and wring every last bit of performance out of it with some clever tweaking, optimizing, and overclocking. Maxing out your PC's performance is no longer the domain of those willing to water-cool their PCs and adjust a plethora of MSI Afterburner sliders. Many serious performance boosts only need a simple BIOS setting tweak or a "set it and forget it" option from within Windows. We show you the components you need to look out for, the settings to adjust and the free apps to download to get the computing equivalent of Tesla's Ludicrous mode, only without a huge premium going to Elon Musk.

As we head to the end of the year, we'll be focusing on more money-saving projects. This month, we look at the best free software available for vital PC tasks (page 52), and in coming issues, we'll be building a $1,000 gaming PC, and comparing whether AMD or Intel offers the best bang for buck right now with head-to-head builds. A lot of readers have contacted me about power-saving features, which we'll also look at soon. If you have any other questions, ideas, or suggestions on PC money saving, email me on: editor@maximumpc.com

Of course, it's not all about saving cash—we're *Maximum PC* after all! So this month, we look at upscaling graphics technology. From Nvidia's DLSS tech to AMD's FidelityFX Super Resolution, upscaling is making the games we play today look and play better, improving image quality, and increasing frame rates. It will allow relatively low-powered hardware like mobile phones and portable games consoles to play PC-quality games. Jarred Walton explains how this magic tech is taking over the gaming industry.

Jeremy Laird also continues his forward-looking features series, this month on storage tech. Mechanical hard drives and solid state SATA drives now seem as outdated as floppy drives next to the latest M.2 drives. With speeds doubling every couple of years and PCIe 4.0 drives revolutionizing how games are made for the PS5 and Xbox Series, what next for data storage? Turn to page 44 to find out.

Elsewhere in this issue, we continue our series on Windows 11 tips and how to get the most out of Microsoft's latest OS. We also check out Nvidia's new value offering, the GTX 1630, before the arrival of the new high-powered 4000-series cards from Nvidia at the end of the year!

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's Editor-in-Chief. He built his first gaming PC in 1997 to play Tomb Raider on 3dfx, and has been obsessed with all things PC ever since.

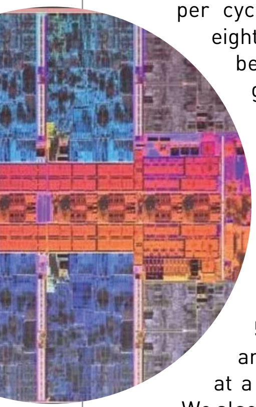
↘ submit your questions to: editor@maximumpc.com

THE NEWS

Processor war kicks off again

Zen 4 lands, with Raptor Lake hot on its heels

THIS FALL WILL see new CPU designs from AMD and Intel, heralding a renewed fight for desktop processor supremacy. AMD's offering hopes to repeat its predecessor's feat by thrashing Intel and being crowned the best gaming chip. Intel responded with its Alder Lake family and the forthcoming 7000-series Ryzen uses the new Zen 4 core architecture, so we start with a decent instructions per cycle bump (about eight to ten percent) before we even get to the other improvements, such as some impressive frequencies.



We've seen a 16-core version running at 5.5GHz, and another being run at a peak of 5.7GHz. We also get a new RDNA 2-based integrated graphics engine, PCIe 5.0, and DDR5 memory. In time we'll get a V-Cache version, with a slab of extra L3 cache on top.

All this may be available by the time you read this. The 7000-series Ryzens should have received their official launch and people will have started the serious business of benchmarking the life out of them. We don't have the confirmed specifications but there are engineering samples everywhere and you can't keep new processor details secret for long. So here is an unofficial breakdown of the first 7000-series Ryzens.

The top chip is the Ryzen 9 7950X with 16-cores and 32 threads. It has 64MB of L3 cache and 16MB of L2 (Zen 4 has twice the L2 cache of Zen 3). The base clock is 4.5GHz, and the maximum boost is 5.7GHz. It has a TDP of 170W and a boost power of 230W. Those clock rates are notable, as the boost is a full 800MHz faster than a Ryzen 9 5950X.

One step down is the Ryzen 9 7900X, running 12 cores at a base clock of 4.7GHz, and a maximum boost of 5.6GHz, another healthy increase over the previous generation. Next is the eight-core Ryzen 7 7700X running at up to 5.4GHz, and a six-core Ryzen 5 7600X with a maximum clock of 5.3GHz. Word is that the chips will carry a premium over their ancestors, as they are built using the more expensive 5nm process. The Ryzen 9 7950X will be at least $800, making it over $200 more expensive than Intel's contender.

Over at Intel, Raptor Lake is rapidly approaching. Again, a new core architecture, but this hybrid design with a mix of performance and efficiency cores won't be along until October at the earliest—red and blue teams often schedule their product launches apart.

Intel buyers get PCIe 5.0 and DDR5 memory too, although Intel will be keeping DDR4 as a lower-cost option. The top chip is the Core i9-13900K with eight performance cores plus 16 efficiency cores for a total of 32 threads. This is double the number of efficiency cores of the i9-12900K. Clock speeds are unconfirmed, but we expect around 5.5GHz, comparable with AMD's Ryzens. However, we've seen engineering samples clocked at up to 6GHz and some being benchmarked. The single-thread performance of the i9-13900K is up over 10 percent over Alder Lake's i9-12900K, but multi-threaded tests do much better, 30 percent faster or more. This points to Raptor Lake being something of a monster in multi-threaded applications, which used to be a stronghold of AMD's designs.

Which will be better, AMD or Intel? Benchmarks give answers, but only to specific questions. Currently, Intel is the winner, but it's close. Both teams will get significantly better players this year, so neither is going to dominate.

One thing Zen did for AMD was to give it exceptional multi-threaded performance. Intel's new hybrid designs look likely to end that advantage. Intel used to be king of the single-thread, and at one point it was the only area where Intel had a clear lead. AMD has gained ground and its V-Cache chip is a single-thread monster.

When the dust settles, we may well find the traditional strengths of each chip family have swapped over. You can argue over the relative merits of AMD and Intel forever, but right now, both are producing strong new designs regularly, sparked by healthy competition between them. This is good for us and good for the PC business. **–CL**

> “Right now, both AMD and Intel are regularly producing strong new designs

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THE GEFORCE BEAST

THE 4090 TI BOASTS IMPRESSIVE STATS

The RTX 3090 Ti; expect the 4090 Ti to look similar.

WE'RE EAGERLY WAITING the next generation of cards from Nvidia with the new Ada Lovelace GPUs, especially the halo model: the GeForce RTX 4090 Ti. This will sport a GPU near the top of the Lovelace tree, an AD102-400-A1, or AD102-450-A1, using close to the full die. There will be a lot of cores: 18,176 or more CUDA cores, 142 or 144 RT cores, and 576-odd Tensor cores. The RTX 4090 Ti will couple this to a whopping 48GB of GDDR6X sitting on a 384-bit bus capable of shifting 1,152GB/s. There is no statistic about this triple-width card that isn't jaw-dropping, including expected power consumption, which has a rumored TDP of 800W, requiring a 1,200W PSU as a minimum and two 16-pin power connectors. Early leaks put this monster at around twice as powerful as the card it replaces. A more modest 450W RTX 4090 is expected to appear first. **–CL**

WI-FI SPEEDS TO DOUBLE

Wi-Fi 7 is on the way

WI-FI IS BASED on the IEEE 802.11 family of standards and major updates are marketed as versions of Wi-Fi. Intel has revealed that it will be ready to launch IEEE 802.11be in 2024, known as Wi-Fi 7. Wi-Fi's protocols are in the care of the Wi-Fi Alliance, a non-profit organization that makes sure everything works together. All kit labeled as Wi-Fi needs to complete interoperability testing and Intel is currently working to get its new version certified.

Intel developed the current standard, 802.11ax and this new version has more bandwidth (320MHz vs. 160MHz) and packs more data. It employs 4096 QAM (Quadrature Amplitude Modulation), alongside other trickery such as Multi-RU Puncturing, Enhanced QoS, and more. The result is a theoretical maximum data transfer rate of 46.1Gbps. The practical speed jumps from 2.4Gbps to 5.8Gbps, over twice as fast as Wi-Fi 6E. Intel is still working on the standard and has hinted that it may be able to squeeze more out of it. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **ROBOT SURGEON**
A remote control robotic surgeon will join the International Space Station for testing purposes.

✓ **RETRO GAMING GOODNESS**
The Sega Genesis 2 Mini retro console is coming, complete with 50 built-in games. It's available for pre-order at $105.

✓ **MICRON'S 232-LAYERS**
Last year, Micron managed 176-layer NAND chips, this year it has reached 232-layers. The talk is now of 200TB SSD drives.

TRAGEDIES

✗ **ANOTHER CRYPTO CRASH**
Crypto firm Celsius has filed for Chapter 11 bankruptcy and withdrawals have been frozen.

✗ **LONE DIABLO IMMORTAL**
A player dropped $100K to level up his character, but his ranking is so high there are no suitable rivals in PVP matches.

✗ **HONDA HACK**
A vulnerability in Honda's keyless fob was found. Rolling-PWN allows cars to be opened and started without a fob.

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INTEL'S ARC STRUGGLES

Hardware delays and driver problems

TWO YEARS AGO, GPUs were in short supply and prices were ridiculous. Intel entered the market promising competitive and available hardware—we were promised four million GPUs in 2022, remember? However, the Arc project has hit a few problems, not least with drivers.

Intel thought it could "leverage the integrated graphics software stack", according to CEO Pat Gelsinger, but that simply didn't work. Nvidia and AMD have years of hard work behind their drivers, Intel hasn't. Performance with DirectX 11 is particularly bad with some titles seeing performance differentials of 50 percent between DX11 and 12. The Arc driver also has features that don't work, such as Smooth Sync. In the meantime, another problem is who will sell the cards? It seems Intel's retailer packages, including the RMA (Return to Manufacturer) support, aren't particularly attractive deals and partners are proving less than enthusiastic about partnering.

The first generation of Intel's cards is based on the Alchemist GPU and gets an 'A' prefix. There are three ranges, the 300, 500, and 700-series. The A750 and A770 have been released, with the A780 to follow. These are aimed at 1440p gaming, comparable to a mid-range RTX 3060. We were set to review Intel's A380 in this issue, but shipping delays meant the sample didn't get to us in time.

The timing is unfortunate too. We're about to see the market awash with cards: both AMD and Nvidia have next-generation kit and plenty of old stock to shift. A third player in the graphics card market is a good thing but so far, Intel's entry has been little more than rattling the doorknob. There have been rumors that Intel may scale back or even cancel future generations of GPUs. Our advice? Cut back the drivers and sell the cards for $50 less than their performance would warrant. **–CL**

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GRAPHICS CARD PRICES FINALLY STABLE

There are even some bargains to be found

GRAPHICS CARD prices are not only back to sensible levels, but some have dipped below MSRP, with bargains to be had. Nvidia's GeForce RTX 3090 Ti was originally $1,999, but versions are now selling for as little as $1,150. In the spring of 2021, when prices peaked, the RTX 3090 was an average of over $3,500, if you could find one. It's a similar story with AMD's kit, although with less dramatic swings. The Radeon 6950 RX is selling at just under MSRP, as is most of the Radeon range.

Alongside retailers' discounts, we have some lowering of MSRPs, or as Nvidia says "promotional pricing". It knocked $500 off the 3090 Ti and $200 off the regular 3090. The 3080 Ti gets a $100 shave and the 12GB 3080 gets an official price of $799. It's not clear how long these price cuts will last, but it's a shame the new pricing doesn't reach into the popular middle tier.

Why have graphics card prices swung from inflated to discounted? Firstly, we have the release of next-generation GPUs from Nvidia and AMD, which will be far more powerful, so better to shift current high-end cards now. Then we have the crypto crash that left miners rushing to sell high-end cards. Of course, we had a certain virus, and shortages have been ironed out, while manufacturing is back on track—just as the demand from people at home has faded away. Now we have too many cards and not enough customers.

So, do you grab a discounted card now, or wait until it has been superseded by the next big thing? If performance is everything then wait. Those 3090 Ti's are being sold off cheap for a reason. Further down the ranking, the choice is less clear. If you've waited for a mid-range card at a reasonable price, the wait is over. **–CL**

Quest 2 gets a $100 price rise

META OWNS OCULUS, and its Quest 2 VR headset has just gone up from $300 to $400 for the 128GB base model. The hike is due to the increased costs of manufacturing, but to sweeten the deal, Meta will bundle in *Beat Saber*, a musical game in which you swipe at colored blocks. Meanwhile, Meta is working on Project Cambria, a high-end augmented reality headset designed specifically for the Metaverse. This uses plastic 'pancake' lenses that are slimmer and lighter than traditional glass designs. The headset has a resolution of 2160x2160 per eye, and is due later this year at $800, to be followed by a lower-cost Quest headset.

Meanwhile, Meta's foray into VR has attracted legal attention. A company called MetaX has filed a trademark infringement case, claiming its VR business has been hindered. Meta's due diligence team must have known and, no doubt, this is a legal problem that can be solved with money. A more serious case is brewing from the FTC over an alleged monopoly in fitness VR. Meta recently bought Within, the people behind the fitness app *Supernatural*, meaning Meta now owns the two leading fitness VR applications. That's a stretch, as the other fitness app is *Beat Saber*, a game that hardly presents as a serious part of any fitness regime.

This is the latest in a slew of similar cases over Meta's market dominance (it currently has 70 to 80 percent of the headset market) and this one seems less like a serious attempt to stop something specific but rather a reminder that the FTC is watching Meta closely and perhaps feels bad about letting Meta buy its way to dominance in the first place. VR as the next big thing is a tired old trope these days. What is clear is that if it is ever finally going to be big, Meta plans to be king of it—and that doesn't play well with others. **–CL**

Meta's Quest 2 VR headsets get a surprise $100 price hike.

HDDs to reach 30TB

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The death of the HDD, predicted for many years, never seems to arrive. Of the two players in the game, Seagate has just employed its Heat-Assisted Magnetic Recording technology (HAMR) to build drives promising capacities of 30TB or more. These are due next year, and by 2026, they are expected to reach 50TB. Western Digital's biggest drive is 26TB, currently the world's biggest. The size of a top game installation tells us why we still use HDDs. Games regularly consume over 100GB, with some managing over 200GB. Like closet space, no matter how much storage you have, software soon manages to fill it. **–CL**

Ethereum goes PoS

Ethereum, the second biggest cryptocurrency, is moving from Proof-of-Work to Proof-of-Stake. It started the PoS Beacon Chain in December 2020 and is now making the jump. You no longer need racks of GPUs to mine Ethereum—instead, coins are created based on each node's holdings of that coin. Power consumption will be reduced by 99.5 percent.

The price of Ethereum is expected to take a hit, but long-term stability will improve as factors, such as electricity prices and GPU availability are removed from the equation. Other cryptocurrencies are expected to switch to PoS or similar systems over the next few years. The days of the PoW cryptocurrency may be numbered. **–CL**

© SEAGATE

Jarred Walton

TECH TALK

Nvidia's Monstrous AD102 on Approach

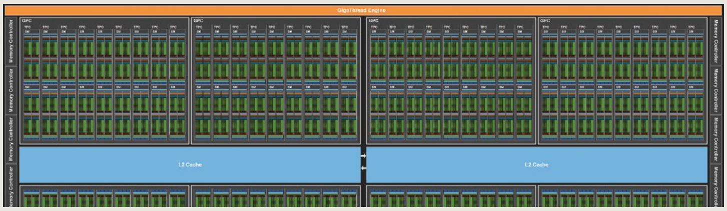
WORD ON THE STREET is that we could see Nvidia's Ada Lovelace GPUs launch in the next few months. Nvidia isn't saying much, but the number of leaks is a sign the hardware is nearing completion and may be getting into the hands of early testers and add-in card partners. The latest rumors, if true, indicate the ultimate Ada graphics card will be an absolute monster.

Many of the core specs haven't changed much since the Nvidia hack earlier this year. We're expecting a GPU built on TSMC's 4N ("4nm Nvidia") custom process node, similar to that already being used for Hopper H100. Like the H100, the AD102 chip will have eight Graphics Processing Clusters (GPCs), with 18 Streaming Multiprocessors (SMs) per GPC, and 128 FP32 CUDA cores per SM. That yields a maximum configuration of 18,432 CUDA cores.

By way of comparison, the current RTX 3090 Ti with the full-fledged GA102 GPU only has seven GPCs, 84 SMs, and 10,752 FP32 CUDA cores. Of the potential 144 SMs, the top model will supposedly have 142 enabled, giving 18,176 shaders. Or put another way, AD102 will have up to 71 percent more shader processing cores than GA102.

The top-tier solution will come with up to 48GB of 24Gbps GDDR6X memory—double the VRAM of the RTX 3090 Ti, with 14 percent higher clocks. As I said, none of this is new information, but then we get to the real kicker. This performance king will come with two of the new 16-pin PCIe 5.0 power connectors, each of which can provide up to 600W of power. No, we won't be getting a 1200W graphics card—at least we hope not!—however, there are reports that the top SKU could be rated for 800W of power consumption.

Even if such a card can double the performance of the current RTX 3090 Ti, that's a ridiculous amount of power for a single graphics card. It also illustrates once again the lack of efficiency scaling at the top of the performance stack. Double the performance and double the power? The only thing we'd be getting from TSMC's 4N process would be transistor density, which means power density would likely double as well. How in Hades would you even cool an 800W card?



Will it be the RTX 4090 Ti, or is a new Titan in the works?

© NVIDIA

There are many caveats we need to mention, like the fact Nvidia maintains radio silence and no one has posted pictures of these supposed cards. Maybe Nvidia has a test board with two 16-pin power connectors to see how far it can push the new GPU but won't release such a card to the public. We've seen partner cards for the current generation push beyond the 500W mark, so 800W for a next-gen card isn't out of the question.

Interestingly, the next step down from this beast of a graphics card looks far tamer. It will only have 128 SMs and 16,384 CUDA cores, 24GB of memory, and a TBP power rating of just 450W. Basically, it will land in the same power envelope as the RTX 3090 Ti while providing potentially 50 percent more performance. We've noted in the past that GDDR6X tends to use a lot more power than GDDR6, like how the RTX 3070 Ti with GDDR6X has a 290W TBP compared to 220W for the GDDR6-equipped RTX 3070. Even so, 350W for double the VRAM seems more than a bit excessive.

We have to wonder if the 48GB card might mark a return of the Titan brand. The Titan RTX back in 2018 was the last time we saw a Titan, with the 3090 and later 3090 Ti filling that same niche with Ampere. Only certain professional and prosumer workloads tend to benefit from the 24GB on the 3090 series, so doubling down and moving to 48GB would be extreme for anything outside the professional space.

Needless to say, a 48GB GDDR6X card with 99 percent of the AD102 GPU cores enabled won't come cheap. Even if it's not called a Titan, we could see a return of the $2,499 Titan RTX price point. We should know more by next month.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

THE TOP FIVE DDR5 RAM

AFTER A COUPLE OF YEARS of patiently waiting on the sidelines, DDR5 RAM is about to enter the limelight. It's already supported by Intel's 12th generation chips (although they also work with DDR4), but AMD's incoming Socket AM5 platform is going to require the newer memory. At the same time, prices have steadily been coming down, meaning you don't have to worry about remortgaging your house to get on board. So, if you're destined for DDR5, these are the sticks to go for.

KINGSTON
FURY
DDR5
KINGSTON
FURY
FURY
DDR5
BEAST

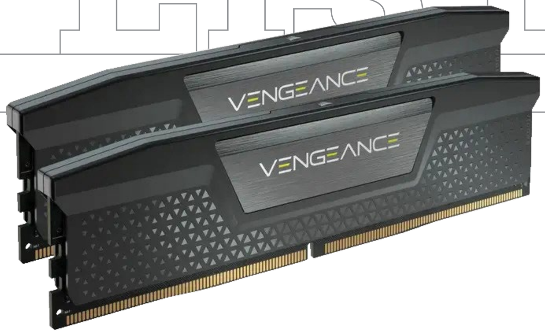
5 KINGSTON FURY BEAST 32GB DDR5-6000 C40

Kingston's kit may feature the words 'Beast' and 'Fury' in the title, but it's actually rather subdued and stealth-like. Those words apply to the performance, particularly the high-frequency 6000MHz speed, while the timings are also good. The real draw of this fast memory kit is its excellent price, with the bonus that it has good heat spreaders. **$280, www.kingston.com**

4 CORSAIR DOMINATOR PLATINUM 32GB DDR5-5200 C38

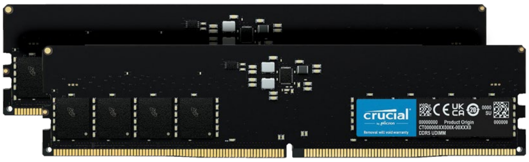
Corsair's Dominator brand has built a reputation for quality and, with its weighty heat spreaders and excellent 5200MHz speed with 38-38-38-84 timings, the C38 maintains that. This kit is all about the RGB lighting, with full integration with Corsair's iCUE system—but it's a tall kit that may block some coolers. **$329, www.corsair.com**

DOMINATOR
PLATINUM RGB



3 CORSAIR VENGEANCE 32GB DDR5-4800MHZ

If you're an average gamer, you probably want 32GB of fast RAM, but not so fast it breaks the bank. If so, this is the kit for you—it's perfect for a budget B660 motherboard, it tolerates overclocking if you're OK playing with the voltages, and it runs cool under load. It's not RGB, but it is low-height, making it a great match for larger CPU coolers. **$210, www.corsair.com**



2 CRUCIAL 2X32GB DDR5-4800 CL40

If memory capacity is your priority, then Crucial has you covered. 64GB DDR5 kits are actually pretty hard to come by as the Intel memory controller struggles with high-density configurations. Thankfully, this kit is fantastic value for money, as it doesn't cost too much more than the 32GB kits listed here. Thanks to its size, this Crucial kit is future-proofed for many years to come. **$350, www.crucial.com**

1 G.SKILL TRIDENT Z5 RGB 2X16GB DDR5-6000MHZ CL36

If you want it all, this is the kit to go for. G.Skill's kit is crazy fast, has great timings, and features subtle RGB lighting. This Trident Z5's 6000MHz speed and 36-36-36 timings hit the sweet spot for high-frequency and tight timings, plus this kit doesn't cost much more than a 5200MHz kit. It's available in both black and silver finishes and non-RGB versions if you prefer the stealth look. **$320, www.gskill.com**

TRIDENT Z5 RGB
TRIDENT Z5 RGB

© KINGSTON, CORSAIR, CRUCIAL, G.SKILL

Jeremy Laird

TRADE CHAT

Alas Intel? Don't panic, it's not that bad…

FULL DISCLOSURE: Previously on this very page, I have detailed several of Intel's recent missteps, including the car crash that is Arc graphics and the built-in platform disadvantages versus AMD that will take several years to solve. But people, please, there is no need to panic.

Despite the building narrative of multi-modal catastrophe at Intel and a stock price that's tanked by about 35 percent in the last few months, the reality is that not much has changed. Most of Intel's current problems were baked in years ago.

At the risk of sounding smug, four months ago, I called it regarding Intel's Arc graphics woes. So, let's just say recent rumors that Intel is seriously evaluating whether it should nuke the whole sorry saga aren't exactly surprising. But here's the thing. Arc isn't Intel's core competence. Intel did not bet the farm on Arc. Should Arc fail entirely, it would be costly and embarrassing, but it's not even nearly an existential issue. It's a bet gone bad.

Another bet gone bad, of course, is Intel Optane and the clever 3D XPoint non-volatile memory tech that underpinned it. Announced in 2015 and first productized in 2017, it's now officially dead. That's a great pity for both Intel and the PC given that Optane was the step-change over NAND flash memory that we'd all been waiting for. But it proved far too expensive. And Optane wasn't Intel's core competence, either. Ostensibly more worrying was the financial data Intel released at the same time as popping a cap in the back of Optane's skull.

Intel's most recent earnings are down a scary 22 percent over the same period in 2021. Add in rumors of Meteor Lake delays and it's easy to understand why some observers think the wheels are coming off. Meteor Lake, of course, is Intel's next-but-one CPU architecture, a radical new modular design using a mix of next-gen Intel manufacturing tech and chiplets farmed out to Taiwanese mega-fab TSMC. Look closer, however, and it is apparent that little of this is unexpected. And for now, it's not hugely worrying.

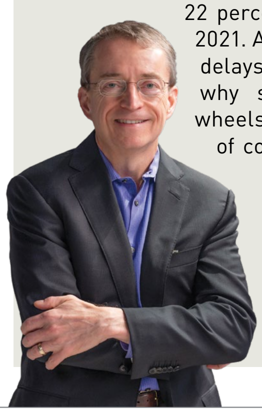
As Intel's CEO Pat Gelsinger himself has pointed out, Optane is merely one of six business units the company has shuttered or sold since his arrival, including the offloading of its drone business to Elon Musk's brother and the sale of its entire SSD operations to SK Hynix. Moreover, it was always going to take years to fix the big problem, namely Intel's manufacturing technology.

Delays in moving from 14nm to 10nm (now rebranded Intel 7) are at the heart of Intel's problems, not Optane or Arc. What Gelsinger, and therefore Intel, cares about is its so-called IDM 2.0 strategy. That involves a two-fold commitment to remain a cutting-edge chip manufacturer and therefore not offload or shut down its chip fabs, and to take that commitment a step further and open its doors to customers. In other words, make chips for third parties in Intel fabs.

If you measure Intel's success by that self-imposed IDM 2.0 metric, it's obvious that neither Optane nor Arc matter all that much. Indeed, the Arc project predates Gelsinger's premiership. So if Arc does blow up, it won't reflect on his strategy at all. Equally, according to Gelsinger, Intel is not expecting to regain its leadership position in terms of chip manufacturing technology until its 18A node comes online in 2025 or 2026. For reference, 18A is a revision of 20A. And 20A comes after Intel 4, the latter being Intel's next production process and due to appear in shipping products next year.

So, the Arc project does look like a bit of a disaster. Intel's revenues aren't pretty. The cancellation of Optane is disappointing. But Intel's fortunes were always going to take years to turn around. It won't be until at least 2025 that the impact of Gelsinger's tenure will become clear. If by then the 20A node is still vaporware and Intel hasn't scored any major customers for its fabs, then OK, the strategy really is failing. Until then, don't panic.

Six raw 4K panels for breakfast, laced with extract of x86… Jeremy Laird eats and breathes PC technology.



©INTEL

> Should Arc fail, it would be costly and embarrassing, but not an existential issue.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> What's Wireguard?
> Missing case features
> USB operating system

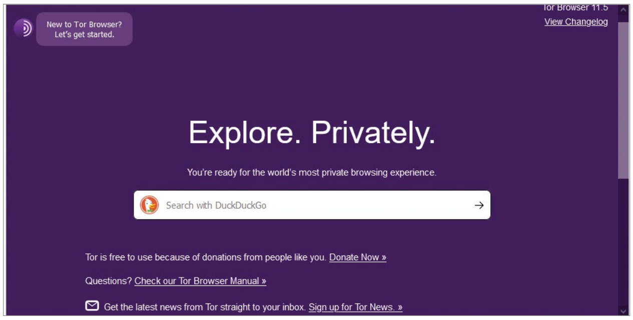
VPN confusion

I found your article on securing your VPN (May 2022 issue) interesting, but I'm slightly confused about WireGuard VPN. Do I have to install this software on my network server, or can I run it just on a desktop or laptop? WireGuard's website is confusing too. On the subject of browser fingerprinting, couldn't I just use my DuckDuckGo browser? I would greatly appreciate any information.

—Ariana Arsenault

THE DOCTOR RESPONDS: Jonni Bidwell's guide to building your own VPN connection should be required reading for anyone wanting to know what a VPN does, what protection it offers, and importantly, what it doesn't offer.

The key thing about VPNs is that there are two basic types: client-based, where you encrypt your internet connection using a third-party provider, and server-based, where you configure a VPN server on your home network. This then allows you to 'dial in' securely and connect to your local network while away from home. Once connected, you have full access to the network and its resources, shared folders, and printers as if you're at home.



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Tor is the web's most private browser.

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Jonni's instructions reveal how to build this type of VPN connection using WireGuard. If you wish to encrypt your internet connection when connected to a public Wi-Fi network, you need a VPN provider that offers Wireguard as a protocol, such as NordVPN, WindScribe, or CyberGhost.

If you're looking to create a VPN server, you'll need to install this on your home network—typically on a device that's on 24/7, which can be a file server on your network or (if supported) your router. Check your router's instructions to see if it supports acting as a VPN server and what protocols it supports—right now, few routers support WireGuard.

In the Doc's opinion, it's simpler to hold off on implementing a Wayland VPN server right now and explore what other protocols your router supports. OpenVPN is the next best choice, but L2TP/IPSec will also do at a pinch—the Doc has such a VPN server configured on his Synology RT2600ac router for dialing home when required.

If you're determined to go ahead with a WireGuard VPN server given its superior performance and security, then if you're relying on your NAS or file server, consider exploring the Linuxserver.io Wireguard Docker image (https://github.com/linuxserver/docker-wireguard)—once configured, you can connect using the WireGuard app in client mode.

Moving on to your other query, it helps to understand what a browser fingerprint is, namely information about your browser (its type and version) as well as other information (your OS, active plugins, language, screen resolution, and so on) that is used to identify you online. Once identified, websites can use it to recognize who you are, track your behavior and serve up personalized ads (among other things).

The DuckDuckGo plugin aims to anonymize your online activity but doesn't hide your browser's unique fingerprint. Various browsers offer differing levels of protection against fingerprinting, from Firefox (part of its standard Enhanced Tracking Protection tools) and Brave (https://brave.com) to the gold standard for privacy and anonymity online, Tor (www.torproject.org).

If you're unwilling to give up your current browser, then look at CCleaner's Kamo (www.ccleaner.com/kamo), a tool that periodically 'randomizes' your browser fingerprint plus offers other anti-tracking tools. The downside is it's not free—it's $25 per year after a 14-day trial.

↘ submit your questions to: doctor@maximumpc.com

Corsair case shortcomings

I am in the process of building my next PC, based on your Alder Lake Machine build in the February 2022 issue, and using the same case and motherboard. I'm getting to the point of connecting the front panel connectors, but the case doesn't have HDD LED or speaker cables. It would have been nice to mention this.

Of more significant concern are the front panel USB cables. The case has USB 3.1 Type-C and USB 3.0 cables. However, the motherboard has a USB 3.2 Gen 2x2 Type C Front Panel connector and a USB 3.2 Gen 1 header. The 3.1 cable fits in the type C connector, but the 3.0 cable would not fit. Is there a workaround for this? Or am I stuck not being able to use some of my USB slots on my front panel?

—Michael Borkowski

THE DOCTOR RESPONDS: Apologies for the omissions, Michael. Sometimes it's the smallest things that escape us. Case speakers can, of course, be purchased separately. Search eBay for 'motherboard speaker' to pick one up for around $2-$3. Corsair's decision to drop HDD lights from its cases is not a new one, but still strange. Ultimately, you'll have to make do with picking up HDD LEDs for around $3-$4 online and then working out where you could place them so they're visible in the case window. You might want to consider a software-based solution instead, one that places an HDD activity light in the Taskbar notification area like Activity Indicator (https://sourceforge.net/projects/activityindicat/).

Regarding your second problem, it's worth noting that USB 3.2 Gen 1 is the new designation for USB 3.0. The USB 3.2 Gen 1 port on the Asus ROG STRIX Z690-E is a standard 19-pin header that should fit any standard USB 3.0 connectors, including those on the 7000D. That said, your Corsair case ships with not one, but two USB 3.0 connectors, each capable of running two of the four available USB 3.0 ports, so you can only connect two ports via the mobo header.

Thankfully, this isn't an insurmountable problem. Look for a PCI-E card that offers additional USB 3.0 (or USB 3.2 Gen 1) headers—Weastlinks has a card with two 19-pin connectors for around $14 (www.newegg.com/p/17Z-010M-00024) that should give you access to all four ports. If you are still unable to plug in your connectors, check the pins on the case cables as they may be bent or damaged.

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Terminal disconnect

I was upgrading my Ubuntu 20.04 LTS server to 22.04 via the cockpit web interface. Part way through the process I nipped off for a coffee, only to come back and find I'd been logged out of cockpit. I thought the installation had finished because the login screen said Ubuntu 22.04, but I hadn't rebooted.

I logged back in and checked for software updates, but whether using cockpit's tool or 'apt get update' in Terminal, I was told jammy had control of apt update. I've waited about 20 minutes and it hasn't let go. I'm afraid to reboot because I can't see what's happening behind the scenes. What can I do?

—William M Brown

THE DOCTOR RESPONDS: Ah, the joy of losing your cockpit session because you wandered off only to discover you've lost your place when you got back. In this case, you're right to be wary, because being disconnected usually coincides with a pause in whatever process you're doing. Thankfully, you can restore the previous cockpit Terminal session with a simple command:

```
sudo screen -D -r
```

Small, light and the perfect external boot drive.

This will take you back to where you left off, where you'll almost certainly discover that the installer is waiting for a response from you—possibly to remove obsolete packages after the installation has finished. Finish the job, then reboot and you should have control of updates once more.

MakeMKV error

Whenever I launch MakeMKV it seems to hang for a while, then throws up a 'No answer from MakeMKVCon' error. I close it and try again, but the same problem. Sometimes, if I open Task Manager to the Details tab, I can see two processes: makemkv.exe, which vanishes after I close the error message, and makemkvcon64.exe, which sticks around for 30 seconds. If I right-click makemkvcon64.exe, choose 'End Task', and wait a few seconds, I can sometimes get MakeMKV to load, but it's a frustrating process. What's the fix?

—Lloyd Bryson

THE DOCTOR RESPONDS: This problem is often caused because you've set the MakeMKV data directory to a location that's no longer accessible, often a network folder. If you're able to open MakeMKV, select View → Preferences and check the destination folder under the General tab. If necessary, change this to a local folder and click OK. That should fix the problem.

If you're unable to get into MakeMKV to make the change, you can edit the setting via the Registry. Open Registry Editor and navigate to Computer\HKEY_CURRENT_USER\SOFTWARE\MakeMKV. Look for the app_DataDir value—this is the one that needs changing. Once done, you should find MakeMKV launches as before.

External boot drive

I'd like to occasionally run a Linux operating system on my PC—not from a live disk, but not using any of my limited NVME boot drive's space either. What's the simplest solution?

—Peter Fairfax

THE DOCTOR RESPONDS: Thanks to the great leap forward brought about by USB 3.0, it's feasible to run Linux (or indeed Windows) from an external SSD drive. USB 3.0 (or USB 3.2 Gen 1) delivers a throughput of 5Gbps, the equivalent of around 500MB/s, which means any external SSD drive will do. However, if you have USB 3.1 (now USB 3.2 Gen 2) ports, you can enjoy double the throughput, in which case choose your drive more carefully to pick one capable of delivering up to 1GB/s throughout, such as Samsung's T7 (from $80 for 500GB, www.samsung.com), for even better performance.

Taking Ubuntu as an example, the install process is relatively straightforward to follow, the key thing being you choose 'Something else' under Installation type. This is the most dangerous part so make sure you have correctly identified your USB drive by size and used space (it won't be dev/sda, which is your Windows drive). Once identified, select the current NTFS or FAT32 partition and click - to remove it, then click + to create an ext4 journaling partition in its place. Once done, select this newly-created partition and let the installer continue.

Now, whenever you want to boot to Linux, simply override your default boot drive at startup (press F11 to bring up the boot menu) and choose your external SSD drive to boot from it. ⏻

BUILD IT, UPGRADE IT, ENJOY IT.

Overclocking may be a dark art but there's no better way of getting free power upgrades and taking your PC to its limits. By *Sam Lewis*

GETTING THE CHANCE to build a PC allows you to make something bespoke to your tastes. Yet even after you've crafted your masterpiece, you may not be getting the most out of your machine. Right now might be a good time to consider whether the mystical world of overclocking is something that you should explore.

As exciting as overclocking sounds, it's important to understand its limitations. It won't make your PC run *Cyberpunk 2077* on full graphics settings if it's currently as powerful as a Nintendo DS.

Overclocking also doesn't mean you have to start with a monster rig but, when starting from scratch, you do have that option. Many of the components in this machine are ideal for futureproofing your system and should have potential performance gains that allow you to squeeze out some extra free power.

We're starting strong here. Our Corsair case is a behemoth with tons of room for heat dispersion—the Airflow in the title hints toward that. We also have six fans that are pulling cool air in and pushing it out and a beastly NZXT CPU cooler to keep things running smoothly when we ramp up the processing power.

We also have arguably the best gaming CPU out there right now paired with a snappy AMD Radeon RX 6900 XT, so the last thing we want is capped performance limited by software and settings. We will piece this system together, take you through how to further set up your machine with the right software, and then some fundamental overclocking to ensure you start off on a strong foot.

INGREDIENTS

PART		PRICE
Case	Corsair 7000D Airflow	$270
Mobo	NZXT N7 Z690 ATX	$300
CPU	Intel Core i9-12900K	$560
CPU Cooler	NZXT Kraken X73 RGB AIO	$225
GPU	XFX Radeon RX 6900 XT 16GB Speedster MERC 319	$900
Memory	32GB (2x 16GB) PNY XLR8 Gaming REV RGB DDR4-3200	$119
SSD	1TB PNY XLR8 CS3140 PCIe 4.0 NVMe SSD	$128
PSU	NZXT C850 80+ Gold PSU	$150
OS	Windows 11 Home 64-bit OEM	$32
TOTAL		**$2,684**

PRICES CORRECT AT THE TIME OF PRINTING

RADEON RX 6900 XT
XFX
NZXT
C850

STEP-BY-STEP BUILD GUIDE PG 22

WHAT'S IN THE BOX?

CPU COOLER

NZXT Kraken X73 RGB AIO

Price: $225

To handle our zippy CPU, we need an effective CPU AIO cooler to keep things under control. NZXT's Kraken lineup has plenty of powerful options to choose from, so we're picking the largest X73 RGB to fill the space in our machine. This features a 360mm radiator and three of NZXT's 120mm Aer RGB fans. This can be controlled via the NZXT CAM software, we will touch on this later.

The CPU header features a fun infinity mirror display with 12 rotational angles of adjustment, so you can make sure the logo is aligned with the rest of the build. This mirrored design ofeers a clean yet artistic look to the build, especially when the RGB elements of the CPU header and the fans are set to white.

This powerful AIO cooler should be able to keep our build nice and cool, even after we turn up the heat with overclocking—and especially with the three additional exhaust case fans that will sit on the top of the Corsair 7000D helping to channel air around this system.

MOTHERBOARD

NZXT N7 Z690 ATX

Price: $300

Motherboards can sometimes look a bit messy and spoil the cleanliness of your build. Although this isn't the first motherboard to be finished in metal covers, this NZXT N7 is one handsome-looking mobo.

This all-black version looks stealthy and its metal shrouds around the PCIe and M.2 ports are magnetic so it's easy to remove and reinstall the covers. The board supports the LGA 1700 12th-gen Intel socket to match with our i9-12900K and has the Intel Z690 chipset.

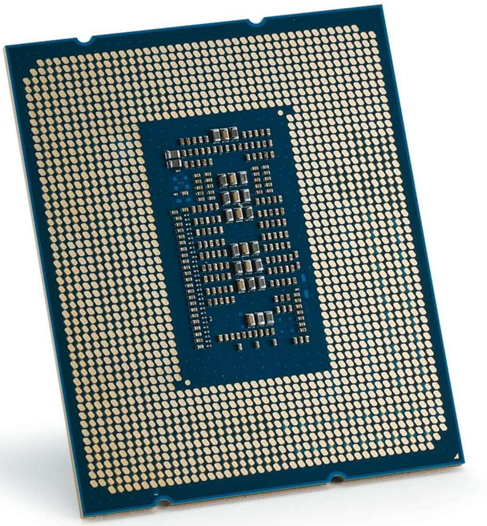
Futureproofing is good on the N7 Z690 although, on this board, DDR5 support isn't present. On the flip side, that's not at a level yet that is leaps ahead of fast-performing DDR4, especially when it comes down to price. It features WiFi 6E, Bluetooth 5.2, and PCIe Gen 5.0 support. These good looks and features come with a substantial price tag though.

STEP-BY-STEP BUILD GUIDE PG 22

CPU

Intel Core i9-12900K

Price: $560



If you want to go all out, this 16-core CPU is one of the best around. Yeah, it's pricey and power-hungry but so is a Nascar—and like the latter, this is one lightning-fast piece of machinery. This Intel offering is more efficient than a roaring V8, featuring a hybrid architecture consisting of eight performance cores for foreground tasks and eight efficient cores for background tasks. This keeps it running at optimum speeds focusing on set cores to tackle different types of tasks at once.

This 12th generation Alder Lake chip is almost certainly overkill for our build right now, but technology progresses rapidly these days and we are sure it won't be long until this chip gets knocked off its pedestal.

And yet it still has plenty of shelf life left. It has a fast single-thread performance with a max turbo frequency of 5.2GHz. The bottom line is that even without overclocking, it is an awesome chip for the build.

CASE

Corsair 7000D Airflow

Price: $270

This case will hopefully have the components inside to match its impressive exterior. This is a massive case and makes the Intel NUCs look tiny in comparison. In fact, you could easily place one of these NUCs inside in conjunction with our existing build, now that's an idea, isn't it?

Going back to the case, it features two winged doors, making it easy to access both the main interior of your PC and also the cabling around the back. Speaking of which, there are plenty of cabling channels, access ports, and removable panels to make this ideal for cable management and compatibility. If you are getting into liquid cooling, this case would be a great starting point with more than enough room to work in.

The pros of a large case can also unfortunately be its cons. It's heavy, even without filling it with all the components. Try to think of it as a permanent solution as you don't want to be moving this hefty unit around all too much. In its white format, we have to say it's a great-looking chassis despite its room-dominating size, it comes across as quite sleek.

GPU

XFX Radeon RX 6900 XT 16GB Speedster MERC 319

Price: $900

What's the use in having a top-tier central processing unit without a similarly powerful right-hand man, the graphics processing unit? These two need to stick together like glue, the two processors working in unison to give us lightning speeds in our build.

That's why we've opted for XFX's Radeon RX 6900 XT Speedster MERC 319. This 16GB GDDR6 GPU features AMD RDNA 2 architecture more than suitable for 4K gaming. With a larger V-core than the AMD reference card, its 14+2 phase power design will allow the GPU to function at cooler temperatures, giving it more headroom for overclocking.

It's a clean-looking GPU and it comes with a mounting bracket to stop any sagging on the board. It's a good job too, as this is a fairly heavy unit. It features subtle RGB branding along the front edge, enough to match the rest of our aesthetic. We are excited to get this GPU into our build and see how far we can push it.

MEMORY

PNY XLR8 Gaming REV RGB 32GB (2x 16GB) 3200MHz DDR4

Price: $119

Unlike when we used them in the Teenage Engineering computer-1 case (see September issue), we can now see the vibrant RGB in full action on these PNY DIMM sticks.

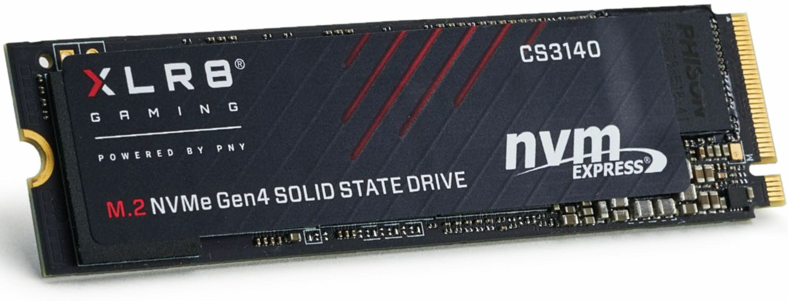
This fast RAM kit runs at 3200MHz with a CAS latency of CL16 which is easily quick enough for what we need. It's just a shame we didn't double up on this kit to fill out our motherboard and give ourselves 64GB of RAM.

The important thing here is that they support XMP 2.0 for memory overclocking, which we will tackle later on in our build. They have been designed with efficient heat spreaders so that when we push this machine further and get some noticeable performance gains, the system should remain cool.

We aren't expecting our rig to double up as a fridge, but thinking about it, that's not a bad idea!

© PNY

STEP-BY-STEP BUILD GUIDE PG 22



STORAGE

PNY XLR8 CS3140 PCIe 4.0 NVMe 1TB

Price: $128

Continuing with PNY's XLR8 gear, we have included the CS3140 SSD into this PC. As we didn't want to disrupt the design of our NZXT N7 motherboard, we opted for the non-heatsink variant, although that does look like an impressive component.

This M.2 SSD has a PCIe Gen4 x4 interface, low power consumption, and 1TB of capacity. It will be able to boot open our games and overclocking software with minimal load times, exactly what you want when building a gaming powerhouse.

The PNY XLR8 CS3140 boasts impressive speed as well. With sequential read speeds of up to 7500 MB/s and write speeds of up to 6850 MB/s, making this a worthy component to be included in our rig.

In hindsight and for better futureproofing, the 2TB model is more appealing—although it does cost an additional $97 over the smaller model we have included here.

PSU

NZXT C850 80+ Gold

Price: $150

There's no getting around it, this system will be resource hungry. Even though our 16-core i9-12900K features a hybrid architecture by splitting its cores into performance and efficient cores, it will use a lot of power. That's without even mentioning our Radeon RX 6900 XT GPU and we will be increasing the consumption even further when we overclock. So that leaves us with NZXTs C850 PSU to keep things under control.

This modular power supply comes with an efficiency rating of 80+ Gold and when the PC is not under full load it has a zero RPM fan mode to run quietly. We also love the NZXT cases that the modular PSU cables come in. We reuse these all the time and feel like they don't get enough praise. So, here it is—thanks NZXT!

FREE POWER? COUNT US IN

PIECE TOGETHER AN OVERCLOCKING GAMING MENACE

LENGTH OF TIME: **1-2 HOURS**
LEVEL OF DIFFICULTY: **EASY**

NZXT
RADEON 6900 XT
XFX
C850

1 TEARING APART THE BEAST

THIS CASE has plenty of panels, covers, and trays that need to be removed first before we start piecing together our PC. Getting it onto our workstation was as fun as you can imagine, so to remove some weight we started by taking off the wing doors. These panels are secured by one screw each from the top. Simply loosen these and then pull the doors upwards. They sit on vertical hinges which makes it easy to lift them on and then re-install.

We won't need these until the end so we recommend putting them back into the PC box, just add some foam or protection to ensure the glass panel doesn't get damaged. Anyway, once both the front panels are removed, we can take off the fan grills and covers, which are easily popped off with no screws in sight. We'll also be removing the three case fans and the HDD mounting trays found at the bottom of the case. We can't put aside the three fans but the undertrays can be put aside, it's SSD only for this machine.

4 ATTACK OF THE FANS (EPISODE II)

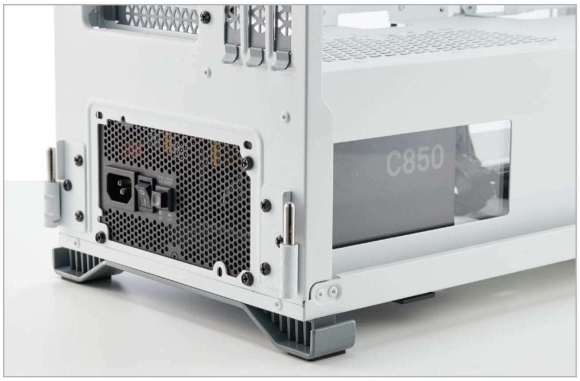
RIGHT, THAT'S IT for the *Star Wars* puns. So after the AIO is in the front of the case, we can re-install the Corsair case fans at the top of the case. This will result in us having three fans pulling air in from the front, and three exhaust fans on the top pushing out that hot air. Plenty of flowing air then for this Airflow case.

To install the fans, it's just the same as the AIO install, minus the radiator and the long screws. Tighten four screws on each fan to the top grill of the case. There's no need to overtighten either, also like the AIO fans, make sure you route the cables through the back. We can connect them to the case fan controller on the back at this stage too.

2 SWITCHING THINGS UP

IN AN UNFAMILIAR FASHION, we are installing the PSU to the build first. That's not normally how we rock, but we are going with it this time. This has been made even easier with the removal of the hard drive mounting trays. On the downside, it will add even more weight back to the case but by this point, we had come to the inevitable conclusion that this was never going to be a lightweight PC.

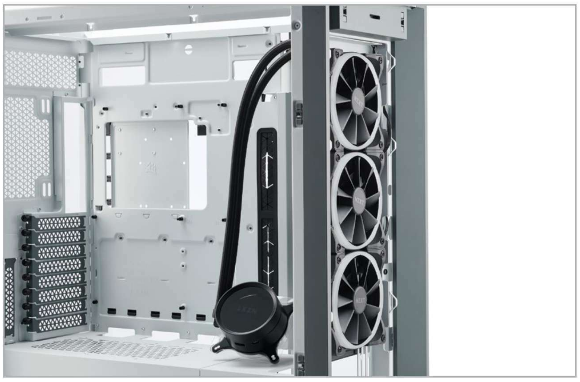
To install the PSU, make sure the fan is facing downwards in this instance and align it with the back of the case. There should be enough holes in the case to match up with the screw holes in the PSU. Unfortunately, the top left screw had to be abandoned as it didn't quite line up. Three screws are enough to keep this PSU secured to our case though.



3 THE FANTOM MENACE (EPISODE I)

AS WE'VE REMOVED the Corsair case fans from the front, we now can add in our 360mm radiator and the three 120mm Aer RGB fans from our NZXT X73 CPU cooler. Make sure that when you put the radiator in, the hoses come from the top of the radiator. This ensures more efficient cooling and will make attaching the CPU header to the CPU a lot easier.

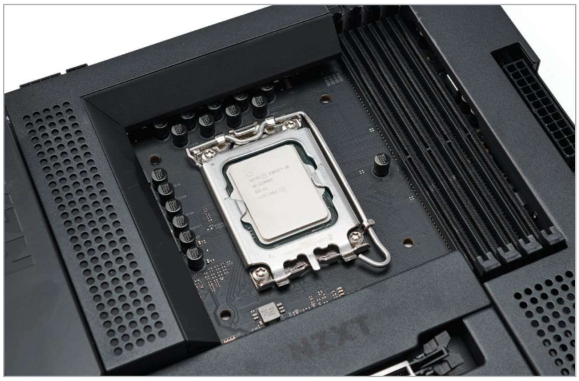
We positioned the case upright, sat where the back I/O shield is. This meant we could hold the radiator on the underside of the front of the case, then we could place the fans on top to align correctly. Once the alignment is set up, take the screws from the AIO cooler box and tighten the fans in place. Use washers, be careful not to screw straight into the radiator, and think about where to run the fan cables.



5 ENTER THE MAIN HUB

AS THE FANS are virtually sorted, we can turn our attention to the PC's motherboard. We will be attaching all of our components onto the board outside of the case before we install it. Our motherboard came with some foam packaging so when working on it, we rested the mobo on top of that. Our first component to find its home is our Intel Core i9-12900K.

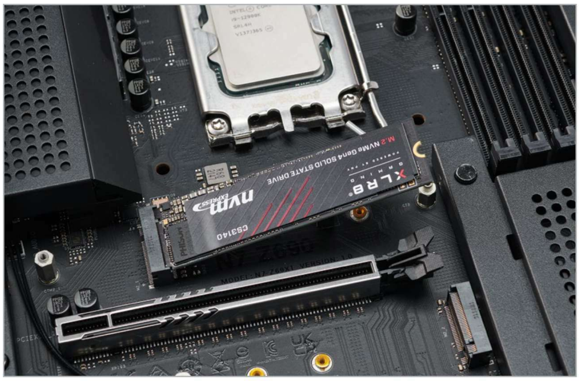
With the Alder Lake 12th generation of CPUs moving from a square to rectangular design, it's even easier to install. Lift the retention arm on the motherboard next to the CPU socket to open the bracket. Then we place our CPU in the socket, making sure to hold the sides, and match the CPU and motherboard arrows together. Once done, bring the retention arm back down and pop off the little black cover.



6 STORING THE STORAGE

OUR PNY XLR8 SSD will be making its way over to the uppermost M.2 slot on our motherboard. This was covered by some of the NZXT N7's metal covers but these are all magnetic and come off in no time at all. Simply lift from the left side of the cover and give it a little slide. Once these are off we can put them to the side and reattach them later.

To insert the SSD, we also need to take one of the tiny M.2 screws from the motherboard's box. There were a few spares here that came in handy—trust us, you do not want to drop one of these. Then to insert the SSD, slot it into the M.2 port at a 30° angle. After that, hold it down flat and screw it into place. Then it's a matter of simply attaching the magnetic shrouds back onto the board.



7 MEMORY OF THE RANDOM VARIETY

WHEN YOU DON'T have four sticks of RAM to slot into your DIMM slots, the ordering is important, so always refer to your motherboard's manual. Indeed, we always have it at arm's reach—no matter how many times you build PCs, something will pop up out of nowhere that throws you off course. In our case, we had to populate DIMM slots 2 and 4.

RAM is one of the easiest components to add, remove and switch in a build. To open up the slot, press down on the clips to pop them open. Then all you need to do is align the notch in the slot with the gap on the pins of your RAM sticks and push them down into place. You'll hear a satisfying click letting you know that your memory has been successfully installed.

8 SECURING THE BOARD

BEFORE WE ADD the GPU and CPU header, we need to insert the mobo into its final resting place. To avoid any shorting, it's important to use as many of the standoff screws as possible when doing this step. First, line up the motherboard's I/O shield with the gap in the back of the case. Rest it down into the case, making sure that all the screw holes align with the standoffs. Take a long magnetic screwdriver and tighten it into place gradually, working diagonally to apply even pressure.

Putting the motherboard in will make attaching the CPU cooler header a much easier job. If we attach this first, then we may struggle to fit the motherboard and it will just cause unnecessary headaches.

11 ADDING THE GPU

AFTER THE FIRST end of the GPU mount is secured, we need to remove some of the metal PCIe shrouds on the back of the case to make room for our GPU. To find out which ones to remove, hold the GPU in the mount position, unscrew the shrouds, and put them somewhere they won't get lost.

After that, we can get on with installing the graphics card. Line the connector up with the uppermost PCIe port on the motherboard making sure that the clip on the mobo is open. Push this down and, like our RAM installation, it will give you a reassuring click when it secures in.

Then the other side of the GPU mount will align up with the case screw holes for the PCIe covers on the back. Simply use the pre-existing screws to tighten these together. This will then give the graphics card much more rigidity as it is attached to both the motherboard and the case.

RADEON RX 6900 XT
XFX

12 CONNECTING THE DOTS

JUST WHEN YOU THINK it's all over, the real fun begins. If we want our PC to do anything more than just look like an interesting dust collector, we need to connect up all of our case, fan, and PSU cables. As these are the thickest of the bunch, we will be installing the PSU cables first.

With plenty of room left underneath the case, fitting the cables in there first was quick and easy. Usually, the most frustrating part is connecting the CPU cable to the top left of the motherboard but, thankfully, this case has plenty of space. Once we have connected our 24-pin, PCIe, SATA, and CPU cable from PSU to the motherboard, we can turn to the fan cables. To enable RGB, we had to use the NZXT daisy chain cables from the box to link each fan together. These connect to the CPU header via the Micro USB connection on the block.

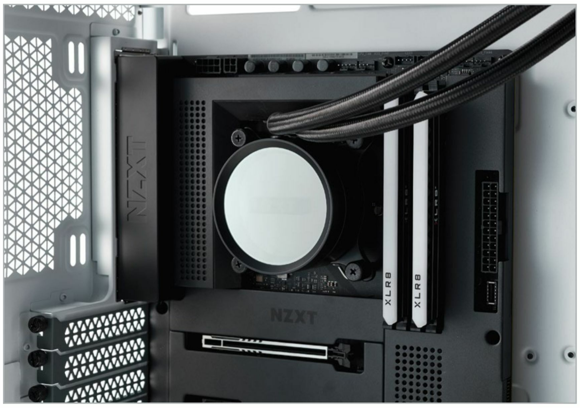
We then linked its other connector straight to the motherboard's CPU fan header. Always turn to your component's manuals when connecting cables as the slightest difference can result in parts not working properly.

Finally, we were left with the usual front panel case connectors to enable the USB ports and power switches to work. Unfortunately, these were individual pin headers and we had to refer to the motherboard's manual before we were able to insert them in the correct position.

9 COOLING THE CPU

IT'S TIME TO get the CPU block in. We turn to the back of the case and add the bracket to the back of the board first so we can install our standoffs. This rubberized bracket slots easily into the back of the motherboard as it is adjustable. Once done, we go back to the front to add the standoffs. Make sure you're using the correct labeled ones from the cooler's retail box. These tighten into the bracket we installed.

Next, take the CPU block and align it with the standoffs. Our block came pre-installed with the LGA1700 bracket and thermal paste. If yours doesn't, add a pea-sized blob to the center of the CPU and place the cooler block on top. Take the four thumbscrews and tighten them into position.



10 MOUNTING MOUNTS

LARGE GPUs bring a lot of power to the table but also plenty of weight. GPU sagging is something you see a lot of unfortunately when building a PC. With the graphics card PCIe slot being off-center, it's inevitable that your GPU will not sit horizontally flush. For PC enthusiast folk, such as ourselves, even if the PC is the quickest, boldest, and flashiest machine ever, sagging bugs us to the nth degree.

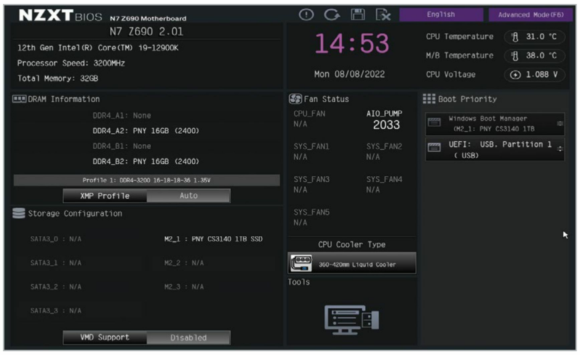
The next best thing is to use a GPU mount and our XFX Radeon RX 6900 XT came with one. This is an easy install that only requires a few screws. Align the mount to the non-port side of the GPU, the main brace bar will run along the bottom of your GPU when it is on the motherboard.

13 THE FIRMWARE

WITHOUT THE BIOS, you can't run a PC, so this vital piece of firmware needs to be running smoothly. Our NZXT N7 Z690 mobo features BIOS flashback which is one of the easiest ways of updating your BIOS.

Using another system, head to the official NZXT page for this motherboard and download the latest BIOS update onto a clean FAT32 USB drive. Rename the file to 'creative.rom' and make sure it is located in the root directory of the drive. Then, turn on the power supply and insert the USB drive into the 'BIOS' USB port on the rear I/O panel.

Next, press the BIOS Flashback switch for about three seconds and the update will begin and start flashing. When the LED stops flashing and it turns off, your update will be completed. Until then, don't press anything.



NZXT BIOS N7 Z690 Motherboard
N7 Z690 2.01
12th Gen Intel(R) Core(TM) i9-12900K
Processor Speed: 3200MHz
Total Memory: 32GB

DRAM Information
DDR4_A1: None
DDR4_A2: PNY 16GB (2400)
DDR4_B1: None
DDR4_B2: PNY 16GB (2400)
Profile 1: DDR4-3200 16-18-18-36 1.35V
XMP Profile: Auto

Storage Configuration
SATA3_0 : N/A
SATA3_1 : N/A
SATA3_2 : N/A
SATA3_3 : N/A
M2_1 : PNY CS3140 1TB SSD
M2_2 : N/A
M2_3 : N/A
VMD Support: Disabled

14:53
Mon 08/08/2022
CPU Temperature: 31.0 °C
M/B Temperature: 38.0 °C
CPU Voltage: 1.088 V

Fan Status
CPU_FAN N/A
AIO_PUMP 2033
SYS_FAN1 N/A
SYS_FAN2 N/A
SYS_FAN3 N/A
SYS_FAN4 N/A
SYS_FAN5 N/A

CPU Cooler Type: 360-420mm Liquid Cooler

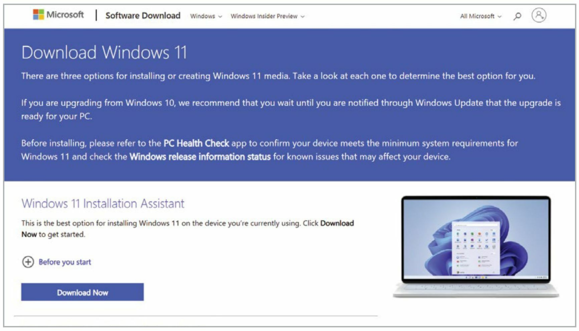
Boot Priority
Windows Boot Manager (M2_1: PNY CS3140 1TB
UEFI: USB, Partition 1 (USB)

© NZXT

14 OS O'CLOCK

AFTER YOUR BIOS has been updated, we need to install the latest Windows 11 OS onto your machine. Using another system, head to the media creation tool page on the Microsoft site and click download where it says 'Create Windows 11 Installation Media'. Make sure you have a clean USB stick of at least 8GB that is formatted to FAT32. Then follow the instructions to get a copy of Win11 installed on the USB drive.

Insert the USB stick into the new build and boot up the system to open up the BIOS. In the BIOS, the boot priority needs to be changed to 'Boot from USB drive'. This will put our USB stick with Windows at the top of the hierarchy so that when we next turn on the system, it loads from the USB. Restart the system and then it should open up the install wizard for Windows 11. Follow this and you should now be able to get cracking with your new PC.



Download Windows 11

There are three options for installing or creating Windows 11 media. Take a look at each one to determine the best option for you.

If you are upgrading from Windows 10, we recommend that you wait until you are notified through Windows Update that the upgrade is ready for your PC.

Before installing, please refer to the **PC Health Check** app to confirm your device meets the minimum system requirements for Windows 11 and check the **Windows release information status** for known issues that may affect your device.

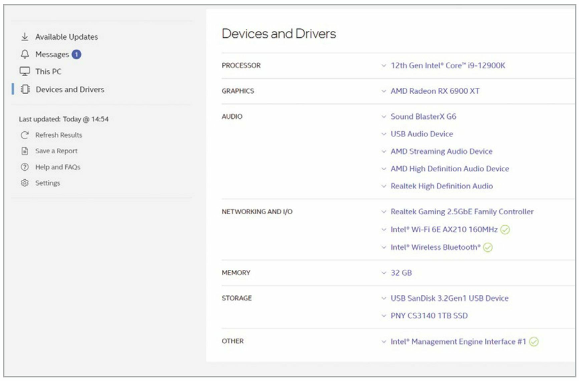
Windows 11 Installation Assistant

This is the best option for installing Windows 11 on the device you're currently using. Click **Download Now** to get started.

15 DRIVERS, NOT THE RACING OR GOLF KIND

OUR PC IS NOW usable, has an updated BIOS and a fresh install of Windows, but we aren't quite ready to get started on a game of *Warzone* just yet. We need to also make sure our Windows 11 system is up to date. Head over to settings, Windows Update, and then click 'check for updates'. If any are available, download and install these.

Next, download the Intel Driver & Support Assistant. This application will check through your system and direct you to the Intel website to download and update your drivers. Lastly, as our GPU is an AMD graphics card, we need to download the AMD Adrenaline software. On the home page, head to Driver & Software and make sure it says up to date. If not, install the latest drivers for your GPU here.

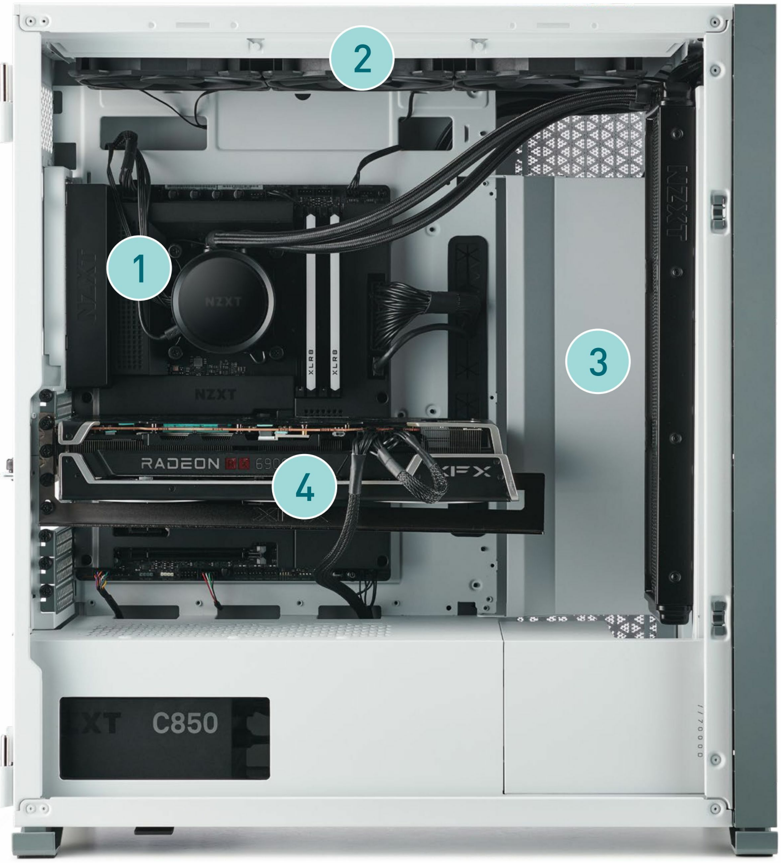


Last updated: Today @ 14:54

Devices and Drivers

PROCESSOR	12th Gen Intel® Core™ i9-12900K
GRAPHICS	AMD Radeon RX 6900 XT
AUDIO	Sound BlasterX G6 USB Audio Device AMD Streaming Audio Device AMD High Definition Audio Device Realtek High Definition Audio
NETWORKING AND I/O	Realtek Gaming 2.5GbE Family Controller Intel® Wi-Fi 6E AX210 160MHz ✓ Intel® Wireless Bluetooth® ✓
MEMORY	32 GB
STORAGE	USB SanDisk 3.2Gen1 USB Device PNY CS3140 1TB SSD
OTHER	Intel® Management Engine Interface #1 ✓

© MICROSOFT



① We love this NZXT Kraken X73 RGB AIO but having two cables coming out of the header creates some untidiness.

② To add some more light inside the case, we could have used three more of the NZXT Aer RGB 2 120mm fans from the front as our top exhaust fans too.

③ It's safe to say there is a lot of space left in this case. "Enough space for some watercooling?" we hear you ask.

④ Custom case cables would have made this build much neater internally.

PRE-OVERCLOCKED BENCHMARKS

BEFORE we get into the nitty gritty of overclocking, we need to check out how well our PC runs before we tinker with it. On paper, considering the components we have, this mighty machine should be more than capable of putting on a show when it comes to gaming. Pairing together the latest and greatest i9-12900K with a GPU as powerful as the Radeon RX 6900XT will make an exciting duo.

We will be initially testing against our 1440p benchmarking build to see how this machine runs unmodified. Then afterward, we will be overclocking and testing against our original scores to see how much of an improvement we can potentially gain for free. And who doesn't like free upgrades?

PRE-OVERCLOCKED BENCHMARKS

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	1,931	2,001 (4%)
Cinebench R23 Multi-Core (Index)	22,111	27,016 (22%)
CrystalDisk QD32 Sequential Read (MB/s)	6,674	7,082 (6%)
CrystalDisk QD32 Sequential Write (MB/s)	4,920	5,300 (8%)
3DMark Fire Strike Extreme (Index)	24,814	28,523 (45%)
Cyberpunk 2077 (fps)	68	98 (44%)
Cyberpunk 2077 RTX (fps)	24	51 (113%)
Metro Exodus (fps)	75	90 (20%)
Metro Exodus RTX (fps)	53	63 (19%)
Total War: Three Kingdoms (fps)	72	108 (50%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our 1440p zero-point consists of an Intel Core i7-12700K, a Zotac Gaming GeForce RTX 3070 Ti AMP Holo, an MSI MAG B660M Bazooka, 16GB of G.Skill TridentZ Neo DDR4-3600, and a 1TB Samsung 980 Pro. All games tested at 1440p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

PRE-OVERCLOCKED ADDITIONAL BENCHMARKS

AS YOU CAN SEE, running at 1440p, our machine performed strongly. Sure, we knew this machine was more powerful than the one we were testing but to see some FPS gains of around 50 percent and more was pretty impressive.

We also decided to run some additional games to see how well a range of slightly older titles performed on this PC. It's safe to say that our machine gave some strong results again for these titles on ultra settings. These will also be compared later to the overclocked results. So, now that we have set a new set of additional benchmarks, let's turn things up a notch, crank up the settings, and see what free performance upgrades we can get out of this machine.

PRE-OVERCLOCKED GAMING BENCHMARKS

	ZERO-POINT	
Grand Theft Auto V (fps)	91	00 (00%)
Alien Isolation (fps)	164	00 (00%)
Dirt Rally (fps)	202	00 (00%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our 1440p zero-point consists of an Intel Core i7-12700K, a Zotac Gaming GeForce RTX 3070 Ti AMP Holo, an MSI MAG B660M Bazooka, 16GB of G.Skill TridentZ Neo DDR4-3600, and a 1TB Samsung 980 Pro. All games tested at 1440p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

IN CONCLUSION

OUR FIRST IMPRESSION is that we prefer the white variant of the Corsair 7000D Airflow, although the black case's interior hides messy cables better. Talking of cables, we wish we'd chosen neater braided ones, especially the PCIe cable that connects to our GPU, which sticks out like a sore thumb. It's a shame as the GPU with its subtle RGB branding and mount sits proudly in this behemoth of a case.

The case has multiple routes for cable management making this build easy to piece together in the final stages. Due to its large size, you will have to plan out the cable routes in case they are too short—it seems like the size of this case is both a plus and a negative. You won't struggle for space when piecing it together but components can look lost within the chassis. As mentioned in our annotations, we'd have loved to include more of the NZXT fans found at the front of the PC. This isn't a crazy RGB build, but it could have benefited from a soft interior glow.

Our results from the pre-overclocking benchmarks were great but weren't exactly shocking. On paper, this is a tasty-looking build and it proved us right! It gives us faith that this will make for a reliable futureproof build with scope for improvement down the line. The i9-12900K is the brain you should add to your gaming rig if you want the best right now. It's a great performing CPU and should last a long time in your new PC. The 'K' in this model's name also means that this chip is unlocked and ready for overclocking, so is ideal for this rig.

So, we are more than happy with how this machine performs. The build itself went smoothly with no hiccups for once and everything booted up just as it should. We aren't necessarily superstitious but is this too good to be true? All that's left to do now is to attempt to overclock this rig. We have spent all this time creating this build, so we may as well squeeze as much power as we can from it.

We ran the *Battle* benchmark in *Total War: Three Kingdoms* and got an FPS increase of 50 percent... we can't complain about that!

Join the conversation!

Discuss all things PC gaming with fellow readers at our official forums

forums.pcgamer.com

PC GAMER

NZXT N7 Z690 Motherboard
Main
Overclocking
Advanced
Tool
PC Monitoring
Security
Boot
Exit
Easy Mode(F5)
Overclocking\DRAM Configuration
Target CPU / Cache / BCLK Speed
5200 MHz / 4700 MHz / 100.0000 MHz
Target AVX2 / AVX-512 Speed
5200 MHz / 5200 MHz
Target Memory Speed
3200 MHz
Memory Information
DRAM Timing Configuration
XMP 2.0 Profile 1: DDR4-3200 16-18-18-36 1.35V 2DPC
Load XMP Setting
Auto
Dynamic Memory Boost
Disabled
Realtime Memory Frequency
Disabled
DRAM Reference Clock
Auto
DRAM Frequency
DDR4-2400 (133:18:1)
DDR4-3200
DRAM Gear Mode
Auto
BCLK Frequency
Auto
Description
If [Auto] is selected, the motherboard will detect the memory module(s) inserted and assign the appropriate frequency automatically.
English
Fri 07/29/2022, 14:20:29
DELL
NZXT
RADEON 6900 XT
XFX
C850

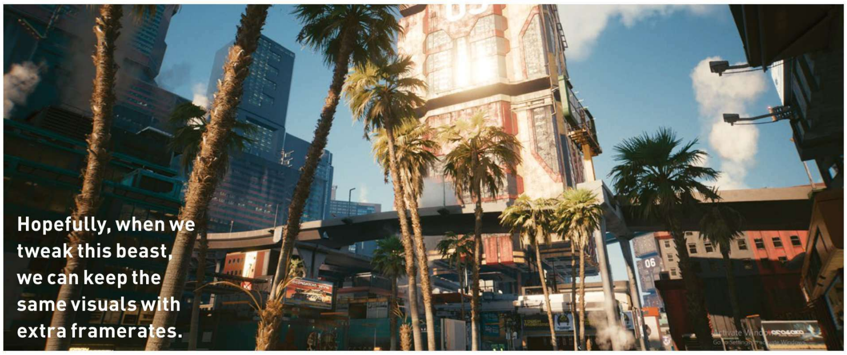
FREE POWER WITH OVERCLOCKING

LEARN THE BASICS AND UNLOCK THE FULL POTENTIAL OF YOUR NEW SYSTEM

IF YOU ARE relatively new to the PC building scene, the word overclocking may send shivers down your spine. But fear not, the reality is not that scary. We aren't aiming to turn your CPU temps up so high that you could huddle around your PC in the middle of a snow storm just to gain a few extra FPS. We will be using simple methods and a variety of tips and tricks to squeeze some extra power from your new build. If you've made the bold choice to buy and build your new PC, then why not aim to get the most out of it?

Overclocking may at first seem like a process only achievable by the most experienced underground hackers on the deep underbelly of the dark web, but it's much easier than you may think. One thing to be aware of though is that there is always the potential to fry your components. So, when attempting to overclock, always test in small increments as having to buy new parts won't make this a free upgrade anymore. We will be using tools such as MSI's Afterburner, MSI Kombustor, NZXT's CAM software, and the Intel Extreme Tuning Utility to improve this already impressive machine.

Another area we will head into is the systems BIOS. This is another part of the PC underworld that can appear daunting at first glance. However, when you get to grips with the layout and learn how to navigate around, any initial fears will soon vanish. We advise you to check through your BIOS just to get familiar with how it operates before starting overclocking. On boot up or restart, hit the F2 or DEL keys when prompted to load into your BIOS. The 'easy mode' is the best way to start having a look around your BIOS.

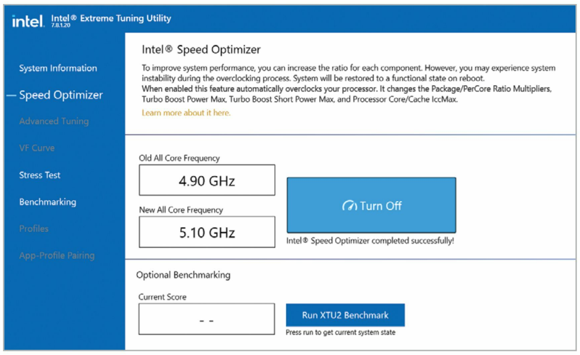

Hopefully, when we tweak this beast, we can keep the same visuals with extra framerates.

© SEGA, CD PROJEKT

HOW TO START OVERCLOCKING

1 ONE CLICK OVERCLOCKING

TO OVERCLOCK YOUR CPU quickly, we can use Intel's Extreme Tuning Utility. Head over to the official Intel site to download this application if you are using a 12th gen Intel CPU. Then once you've installed it, go to the speed optimizer panel on the left and click the big blue 'optimize now' button. It's as simple as that. This takes our old all-core frequency from 4.90GHz to 5.10GHz—not a bad improvement for just clicking a few buttons. There's even an XTU2 benchmark built in. Before optimizing we got a score of 8914 marks and after we got a score of 9570 marks. That's one easy upgrade.



Intel® Speed Optimizer

To improve system performance, you can increase the ratio for each component. However, you may experience system instability during the overclocking process. System will be restored to a functional state on reboot.
When enabled this feature automatically overclocks your processor. It changes the Package/PerCore Ratio Multipliers, Turbo Boost Power Max, Turbo Boost Short Power Max, and Processor Core/Cache IccMax.

Learn more about it here.

Old All Core Frequency: 4.90 GHz
New All Core Frequency: 5.10 GHz

Intel® Speed Optimizer completed successfully!

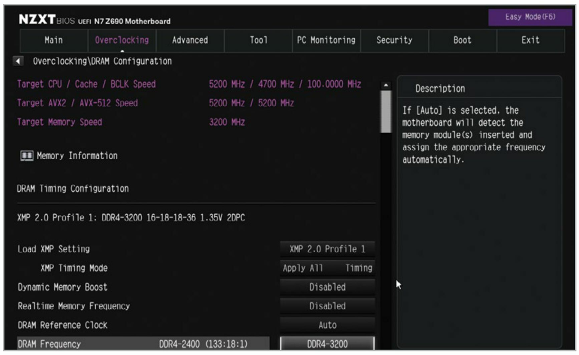
Optional Benchmarking

Current Score: - -

Press run to get current system state

2 RAM OVERCLOCKING

SIMILAR TO THE ONE-CLICK overclocking for the CPU, we can tune the RAM in the BIOS with only a few clicks. Reboot your system and when your motherboard logo appears, mash the DEL or F2 key to open up your motherboard's BIOS. In our NZXT BIOS, we went to the overclocking tab and the DRAM configuration, where you'll find options for XMP settings. It is typically set to AUTO so click and select ' XMP 2.0 profile'. This will overclock your DDR4 memory automatically. Make sure your DRAM frequency is set to the same as stated by the manufacturer, for example, we set ours to 3200MHz.



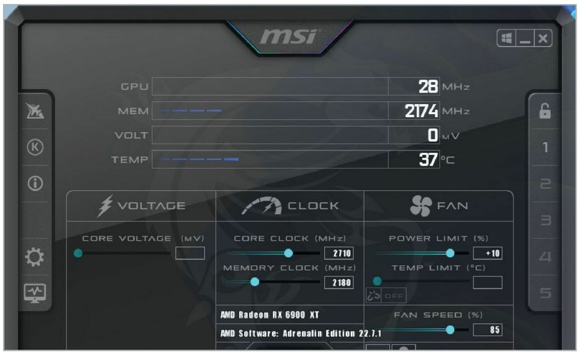
```
Overclocking\DRAM Configuration
Target CPU / Cache / BCLK Speed        5200 MHz / 4700 MHz / 100.0000 MHz
Target AVX2 / AVX-512 Speed            5200 MHz / 5200 MHz
Target Memory Speed                    3200 MHz

XMP 2.0 Profile 1: DDR4-3200 16-18-18-36 1.35V 2DPC

Load XMP Setting                                        XMP 2.0 Profile 1
    XMP Timing Mode                                     Apply All    Timing
Dynamic Memory Boost                                    Disabled
Realtime Memory Frequency                               Disabled
DRAM Reference Clock                                    Auto
DRAM Frequency              DDR4-2400 (133:18:1)        DDR4-3200
```

If [Auto] is selected, the motherboard will detect the memory module(s) inserted and assign the appropriate frequency automatically.

3 GPU OVERCLOCKING

TO GET THE MOST power gains from overclocking, we will be tweaking our GPU. When doing so, it's important to go up in small increments and benchmark—go too far and you run the risk of frying your GPU. We will be using two MSI programs, Kombustor (stress test) and MSI Afterburner to tune our PC. In Afterburner, we will be tweaking the clock settings (core and memory) and the fan's power limit and speed. We recommend starting the fan speed at 70 percent and increasing the power limit by 10 percent.

Run the Kombustor stress test and gradually increase the core clock and memory clock sliders to see any changes. In Afterburner, tick to apply these settings, save, and allocate it to a numbered profile on the right. Once the stress test starts to artifact, you are reaching your limit—it's best to stay under this limit to avoid damaging your peripherals.



GPU 28 MHz
MEM 2174 MHz
VOLT 0 mV
TEMP 37 °C

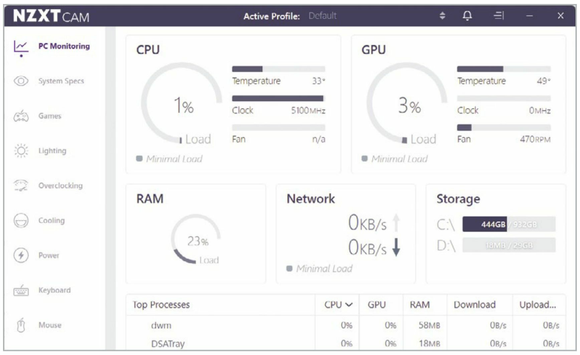
CORE VOLTAGE (MV)
CORE CLOCK (MHz) 2710
MEMORY CLOCK (MHz) 2180
POWER LIMIT (%) +10
TEMP LIMIT (°C)
FAN SPEED (%) 85

AMD Radeon RX 6900 XT
AMD Software: Adrenalin Edition 22.7.1

4 NZXT CAM

IT'S ALWAYS important to have PC monitoring software when overclocking your system. It allows you to keep a tab on how your computer is running and the temperature reached. With any build, we recommend using the monitoring software from the manufacturer of your motherboard—we are using NZXT's CAM application. It follows the same format, making it a clean and simple user experience.

Down the left, you have all of the tools labeled, including an overclocking tab. Like MSI Afterburner, this allows you to tweak the memory clock and power limit but Afterburner has more scope and in-depth settings to tweak to your preference. From the PC monitoring page, you can check your CPU and GPU's load, temps, clock, and fan speed. Press the icon to the left of the minimize button and there's a handy overlay feature so you can see this in real-time.



Active Profile: Default

CPU: 1% Load; Temperature 33°; Clock 5100MHz; Fan n/a; Minimal Load

GPU: 3% Load; Temperature 49°; Clock 0MHz; Fan 470RPM; Minimal Load

RAM: 23% Load

Network: 0KB/s ↑ 0KB/s ↓; Minimal Load

Storage: C:\ 444GB / 932GB; D:\ 18MB / 29GB

Top Processes	CPU ⌄	GPU	RAM	Download	Upload...
dwm	0%	0%	58MB	0B/s	0B/s
DSATray	0%	0%	18MB	0B/s	0B/s

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SO HOW DID WE DO?

IT'S SAFE to say that if you spend your time learning your PC's limits with overclocking then you can see performance upgrades without necessarily taking your system to within an inch of its life. Across the board, we saw improvements in our CPU, RAM, and GPU performance and general gains of around 3-10 percent. With our results already performing so highly, we were glad we could squeeze this extra power out of our system. Put it this way, if it's there to be harnessed, why not do it?

Spending that extra half an hour to an hour going back and forth overclocking and benchmarking can make a difference. It could also be the vital difference between using all of the available Hz on your display or not.

OVERCLOCKED BENCHMARKS

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	2,001	2,071 (3%)
Cinebench R23 Multi-Core (Index)	27,016	27,625 (2%)
CrystalDisk QD32 Sequential Read (MB/s)	7,082	7,130 (1%)
CrystalDisk QD32 Sequential Write (MB/s)	5,300	5,453 (3%)
3DMark Fire Strike Extreme (Index)	28,523	28,816 (1%)
Cyberpunk 2077 (fps)	98	104 (6%)
Cyberpunk 2077 RTX (fps)	51	57 (12%)
Metro Exodus (fps)	90	98 (9%)
Metro Exodus RTX (fps)	63	66 (5%)
Total War: Three Kingdoms (fps)	108	117 (8%)
		0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our 1440p zero-point consists of an Intel Core i7-12700K, a Zotac Gaming GeForce RTX 3070 Ti AMP Holo, an MSI MAG B660M Bazooka, 16GB of G.Skill TridentZ Neo DDR4-3600, and a 1TB Samsung 980 Pro. All games tested at 1440p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

ADDITIONAL RESULTS

FROM OUR ADDITIONAL BENCHMARK on our older favored titles, we also see improvements across the board. Our largest is an 11 percent increase with the new overclocking settings on *Dirt Rally*. This game is seven years old, but with the sliders cranked to the right and played on a high hertz 2K monitor, it still rocks! To make sure your benchmarking is accurate, with each tweak you make overclocking, run three benchmarks at those settings and take an average result.

So, are we happy with our results? The bottom line is yes. Older titles almost feel like they need to be played on the highest settings so they don't appear too outdated, so overclocking on older games is a must to get the best experience possible. ⏻

OVERCLOCKED GAMING BENCHMARKS

	ZERO-POINT	
Grand Theft Auto V (fps)	91	94 (3%)
Grand Theft Auto V (fps)	164	172 (5%)
Dirt Rally (fps)	202	225 (11%)
		0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our 1440p zero-point consists of an Intel Core i7-12700K, a Zotac Gaming GeForce RTX 3070 Ti AMP Holo, an MSI MAG B660M Bazooka, 16GB of G.Skill TridentZ Neo DDR4-3600, and a 1TB Samsung 980 Pro. All games tested at 1440p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

WAR OF THE UPSCALING ALGORITHMS

Rendering fewer pixels to boost framerates

VIDEO UPSCALING is hardly a new technology. From the time the first DVDs started shipping, companies have worked to create higher-quality renditions of low-resolution videos. First, it was VHS to DVD quality, then we got 720p TVs and Blu-ray drives that would turn DVD quality into Full HD quality, and now there are TVs and other devices that will upscale 1080p content to 4K, or even 8K if you have the requisite display and hardware. But upscaling video content is different from upscaling games, in a variety of ways.

For one, games have a lot more data available behind the scenes. They also run at much higher frame rates and are highly susceptible to latency issues. While the underlying concepts of upscaling may be similar, the hardware and technologies behind the scenes are much more complicated.

The proof of the pudding, as always, is in the eating—or, in this case, the rendering of the pixels. Join us as we dive into the current game upscaling solutions from Nvidia and AMD—and even Intel, sort of. Which will reign supreme, or can they all possibly coexist in an increasingly crowded world of GPUs and APIs? **–JARRED WALTON**

© EA

Nvidia's DLSS tech is used in games such as *Battlefield 2042* to get better performance, without sacrificing image quality.

THE NEED FOR UPSCALING

We've seen a lot of hype over the past few years around the topic of upscaling technologies. Nvidia is largely to blame, having launched DLSS—that's Deep Learning Super Sampling to the nerds—not long after the first RTX 20-series GPUs landed in late 2018. The idea wasn't exactly revolutionary: render fewer pixels and then intelligently upscale the result to a higher resolution. Gamers would get better performance, hopefully without losing much in the way of image quality.

The thing is, upscaling tech has been around for decades. Lanczos resampling, for example, is named after its inventor, Hungarian Cornelius Lanczos, who died in 1974. He wasn't using his mathematical formula for video and image processing back in the day, but the principles certainly apply there. It's also a relatively simple algorithm compared with some other alternatives, meaning it can be used without causing a significant loss in performance for things like real-time rendering.

But why do we need upscaling in the first place? If you've paid attention to increasing resolutions over the past decade or two and looked at where things are headed, we're fast approaching a time when only the highest of the high-end graphics cards will be able to handle gaming at native resolutions. Even today, with a top-tier GPU, many games can't break 60fps at maximum quality settings while using a 4K resolution. For instance, *Total War: Warhammer 3* only managed 50fps on the 3090 Ti at 4K ultra and 38fps on the RX 6950 XT. Games with complex ray tracing, such as *Control*, *Cyberpunk 2077*, *Fortnite*, and *Minecraft* averaged 31fps on the 3090 Ti and 17fps on the 6950 XT.

The major upscaling algorithms don't need to use the theory of relativity or the space-time continuum to work, at least not yet.

Now imagine trying to do anything at all with future 8K displays. Four times as many pixels? Performance will implode. Not that most of us need an 8K display, but they're coming regardless, and we'll have far better luck using such a high resolution if we don't have to natively render every single pixel that gets sent to the screen. But even if you don't run an 8K monitor, 4K displays are becoming ubiquitous—nearly every new TV that is launched these days now sports at least a 4K resolution.

That might not be a problem for the fastest GPUs, but anyone running a budget or midrange solution will have to look for some alternative to native 4K gaming.

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Upscaling fills the gap, and it's been doing so quite successfully for some time. The previous generation Xbox One X and PlayStation 4 Pro were both marketed as being 4K capable. Technically, they were, especially with lighter fare. But if you wanted to play a more demanding game on those previous generation consoles, they invariably resorted to dynamic upscaling—and most of the console games never even considered whether that was a problem.

Of course, console gamers have the benefit of typically sitting on a couch that's 10–15 feet away from the TV. The eagle-eyed among you might be able to tell the difference between native 4K rendering and 1080p upscaling at that distance, especially on larger TVs, but for anyone just wanting to enjoy some games, losing a bit of detail while gaining a smoother experience represents a net win. Computer gaming on the other hand typically happens at a monitor distance of two feet, where upscaling artifacts are far more noticeable.

SPATIAL VERSUS TEMPORAL UPSCALING

Fundamentally, there are two core approaches to upscaling: spatial and temporal. Spatial upscaling is far easier to tackle, as everything that needs to be handled can be represented by a single frame buffer. It's like upscaling an image, except that it needs to be done far more quickly than what you would get from a typical image manipulation application. Unfortunately, spatial upscaling also runs hard into a wall that comes from the lack of data.

Upscaling is a form of interpolation—filling in the gaps as you resample a signal into a higher frequency or resolution. There are practical limits to how far you can go with such an approach before there's no longer any real gain. In our experience, doubling the frequency or resolution is within reach. Beyond that, you get severely diminishing returns, or alternatively upscaling artifacts.

Think of the problem in the reverse, and you get a hint of the difficulty of making an ideal upscaling algorithm. If you start with a 4K image (3840x2160 pixels) and cut the horizontal and vertical resolution in half, you get a 1080p (1920x1080) image. It should still look quite good to most people, but it now has a quarter of the data. Do that again to 960x540, and again to 480x270, then 240x135. That's 1/256 as many pixels, and you could go even lower. However, there are effectively infinite source images that could be scaled down to the same 240x135 result. Upscaling tries to undo the loss of data and information, but can only go so far.

Temporal upscaling attempts to improve things by taking multiple frames of data, combining it with additional information like the depth buffer (or z-buffer) and motion vectors showing how each pixel has moved between frames. All that additional data helps to create a better upscaling result. The idea is that any two consecutive frames should be similar to each other. The minor differences in the frames can be used to refine the upscaling result, in effect giving the algorithm more data to work with.

The problem with having more data available is that there's more computational work to be done, and greater modifications to a game's engine might be required. The good news for temporal upscaling algorithms is that most of the work necessary to support just one algorithm can easily be applied to other temporal upscaling solutions—it only needs to be done

A staple of science fiction and spy shows for years, AI upscaling algorithms may never be quite as good in real life.

UPSCALING, HOLLYWOOD STYLE

Our primary focus has been on real-time upscaling used in video games, but upscaling has other applications too. From *Star Trek* and *MacGyver* to *James Bond* and *CSI*, computer image enhancement has long been a way of pulling incredible detail out of blurry images. See that 5x3 block of pixels? Enhance! And like magic, a blocky image resolves into a clearly legible face, reflection, license plate, or whatever.

We're not there yet. In fact, we may never see an algorithm that can take a single low-resolution photo and 'enhance' it into a clear high-resolution photo showing a reflection of a tattoo. However, taking a modest resolution image and upscaling it to a higher resolution without adding a bunch of pixelation has become commonplace, and video sources could also be used to help refine the output, in theory, at least.

As an extreme case, imagine a low-resolution camera taking a video of something, but moving around slightly. With enough frames of data, an 'intelligent' algorithm could eventually turn that video stream into a high-resolution image. Each frame might only be a few dozen pixels, but given hundreds of frames of an object, that could all add to tens of thousands of pixels worth of information.

The problem, of course, would be with getting enough frames of data. A man walking past a surveillance camera might only have his face visible in a dozen frames. Thirty slightly different views of a 5x5 pixel reflection in someone's sunglasses? Sorry, Hollywood script-writers, but that still won't give you enough information to be able to create a detailed 500x500 'enhanced' version with legible text.

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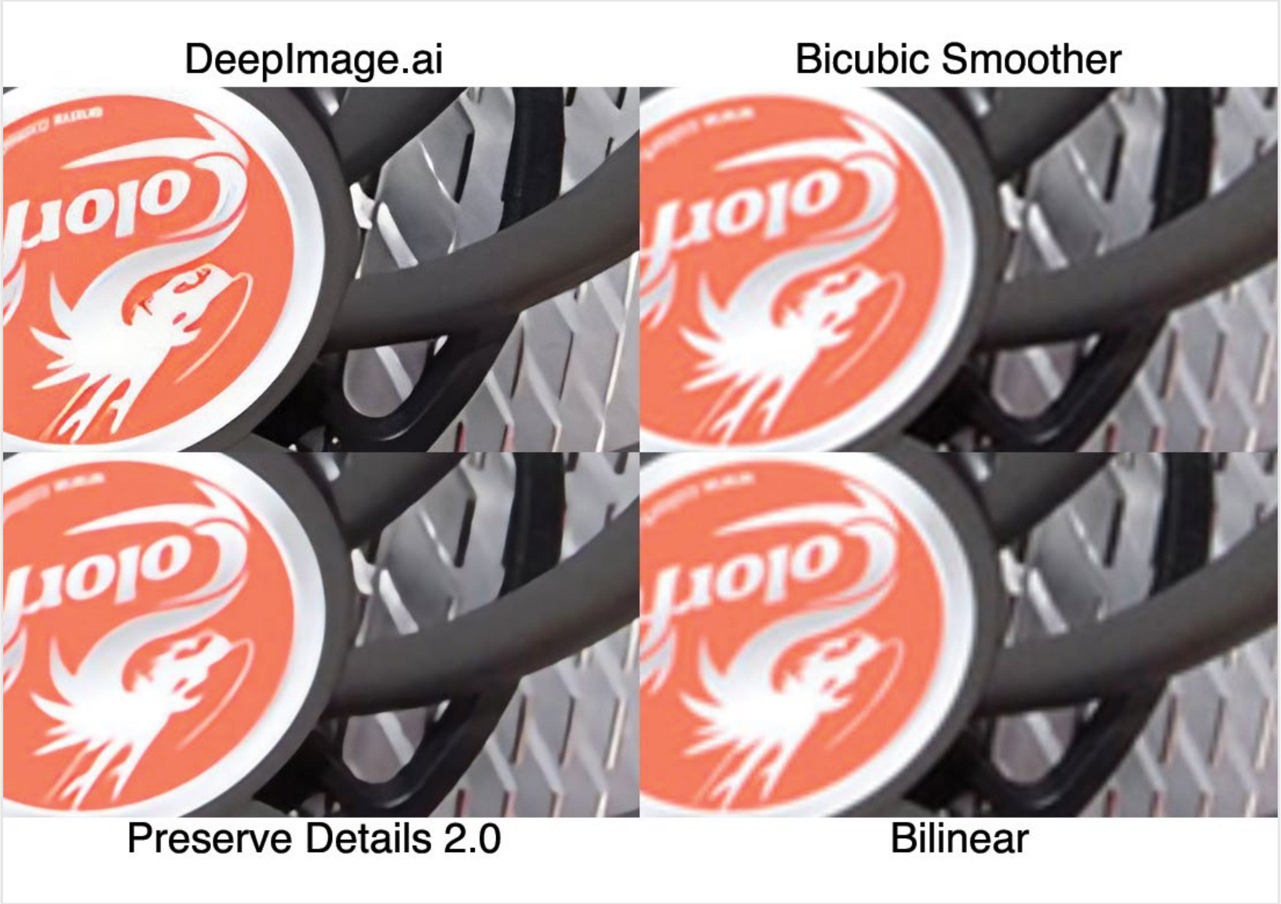

A CLOSER LOOK AT DIFFERENT UPSCALING ALGORITHMS

Examples of 4x upscaling using different algorithms, the equivalent of going from a 960x540 source image to a 3840x2160 (4K) output.

Many examples of upscaling like to start with showing the worst option, nearest neighbor—which hasn't been commonly used as the preferred solution for decent quality upscaling in a couple of decades. Sometimes nearest neighbor might be used for aesthetic purposes, but ever since the 3dfx Voodoo first came to market back in 1996, bilinear filtering has been the baseline for upsampling textures.

Adobe's Photoshop photo-editing program has supported various upscaling algorithms for as long as we care to remember. Some work better than others, and the latest release now has an AI-derived mode called Preserve Details 2.0 that generally works better than previous upscaling options, and it only takes a few seconds. What if you took a similar approach, but instead of running on a local PC, you train and run the upscaling algorithm on massive supercomputers, giving them far more time and computational power? That's what companies such as Deep-Image.ai are doing, offering up to 4x upscaling, with sharpening and denoising.

The problem with bilinear filtering is that it looks blurry, particularly at higher upscaling factors. It uses a 2x2 sampling of pixels to determine the best final color value for each pixel in the result. Bicubic filtering increases the sampling pattern to a 4x4 grid, which often creates a better resulting image. Neither is perfect though, as the lack of data in the source eventually results in a less than perfect result.

Machine learning algorithms attempt to combat that through training. Given millions of examples of high- and low-resolution versions of an image for training, a deep learning network tries to make up for the lack of detail in a source image. The results can be impressive, as shown in the Photoshop Preserve Details 2.0 and Deep-Image.ai results. The AI algorithms show cleaner lines, and in the case of the writing on the Colorful logo (taken from our GTX 1630 review on page 76), you can almost make out some of the words. Except, the sticker says "www.Colorful.com" (upside down), and the "www" looks more like Roman numerals on the Deep-Image.ai result.

once. In theory, a game could support many different upscaling algorithms, providing users with a choice. In practice, we've only seen a few hints of that API utopia so far.

WEARING THE GREEN SHORTS: NVIDIA DLSS

Nvidia deserves credit for a lot of the energy and work now being put into upscaling algorithms. Sure, there were lots of games with varying forms and quality of upscaling in the past, but now it's become something more people care about. *Shadow of Mordor*, to name just one example, came out in 2014 and ran at your desktop resolution. If you had a 4K monitor and a GPU that couldn't provide a playable experience at that resolution, the game would allow you to choose a lower resolution that would get upscaled to 4K. Lots of console games have also used upscaling over the past decade, but again, it wasn't something sexy. DLSS? Yeah, it's sexy.

Nvidia's DLSS algorithm has been trained on perhaps millions of frames' worth of data. It's also been tuned over time to make better use of the training data. Each frame for training consists of a 'ground truth' result with 64 samples per pixel used for anti-aliasing purposes, and a lower resolution non-AA image that represents the input to the algorithm. Feed all of those through the machine learning tools and the algorithm should be able to create upscaled frames without any jaggies.

Like all machine learning algorithms, there's a lot of hand-wavy black box stuff going on. The earliest versions of DLSS (see sidebar) were rather disappointing, but Nvidia hasn't disclosed all the changes made with later iterations. Was it simply a matter of changing the way the network was trained? Or was there custom tuning of the algorithm along with the inputs and outputs that was necessary? Only Nvidia knows that for sure.

Games that want to implement DLSS need to provide it with the frames of data, along with depth buffer and movement vectors. The DLSS black box then takes the results of the previous frame—which used the results of the previous frame, ad infinitum—and, along with the other data, crunches it through the special sauce deep learning algorithm, and spits out a final high-quality result. It sounds almost too good to be true, but DLSS really does result in some decent images, particularly at the highest quality settings.

DLSS typically has three upscaling modes, sometimes four: Quality, Balanced, Performance, and optionally Ultra Performance. These correspond with 2x, 3x, 4x, and 9x upscaling factors, meaning the total number of pixels rendered versus the upscaled result. Performance mode, for example, doubles the horizontal and vertical resolution, while Ultra Performance mode triples them. Note that while Ultra Performance mode can be used at lower resolutions, it's mostly intended to be used with 8K monitors—at least, that's what Nvidia thinks. Feel free to use it however you see fit, though 9x upscaling with a 1080p output isn't going to look great.

The biggest concern most people have with DLSS is that it's a fully proprietary Nvidia-only solution. It requires an RTX graphics card, and if you don't have one, you can't use DLSS. Even Nvidia's own GTX 16-series Turing GPUs are left out in the cold, which means the performance gap between the GTX 1660 Super and the RTX 2060 can be a bit larger than benchmarks show, once you account for DLSS. That's because DLSS uses the tensor cores present in the RTX series graphics cards, which can deliver huge amounts of lower precision computational performance.

The RTX 3080, for example, can do a theoretical 31 TFLOPS of 32-bit floating-point calculations using its traditional GPU shader cores. The tensor cores meanwhile can do up to 245 TFLOPS of 16-bit FP calculations. That's eight times the theoretical computational performance. Is all that compute necessary? That's more difficult to say. Even the lowly RTX 3050, the slowest of all RTX GPUs to date, seems to manage running DLSS just fine. It only has 73 TFLOPS of FP16 compute. But then, an RTX 3050 isn't going to be getting hundreds of frames per second of work to handle—and if it did get such a workload, the tensor cores might become the bottleneck.

DLSS 2.0 has been around since late 2019, which means developers have been using it for over three years now. It's reasonably well understood, integration is available for Unreal Engine and Unity, along with many other game engines,

Minecraft features Nvidia's DLSS upscaling tech, which helps the game both graphically and performance-wise.

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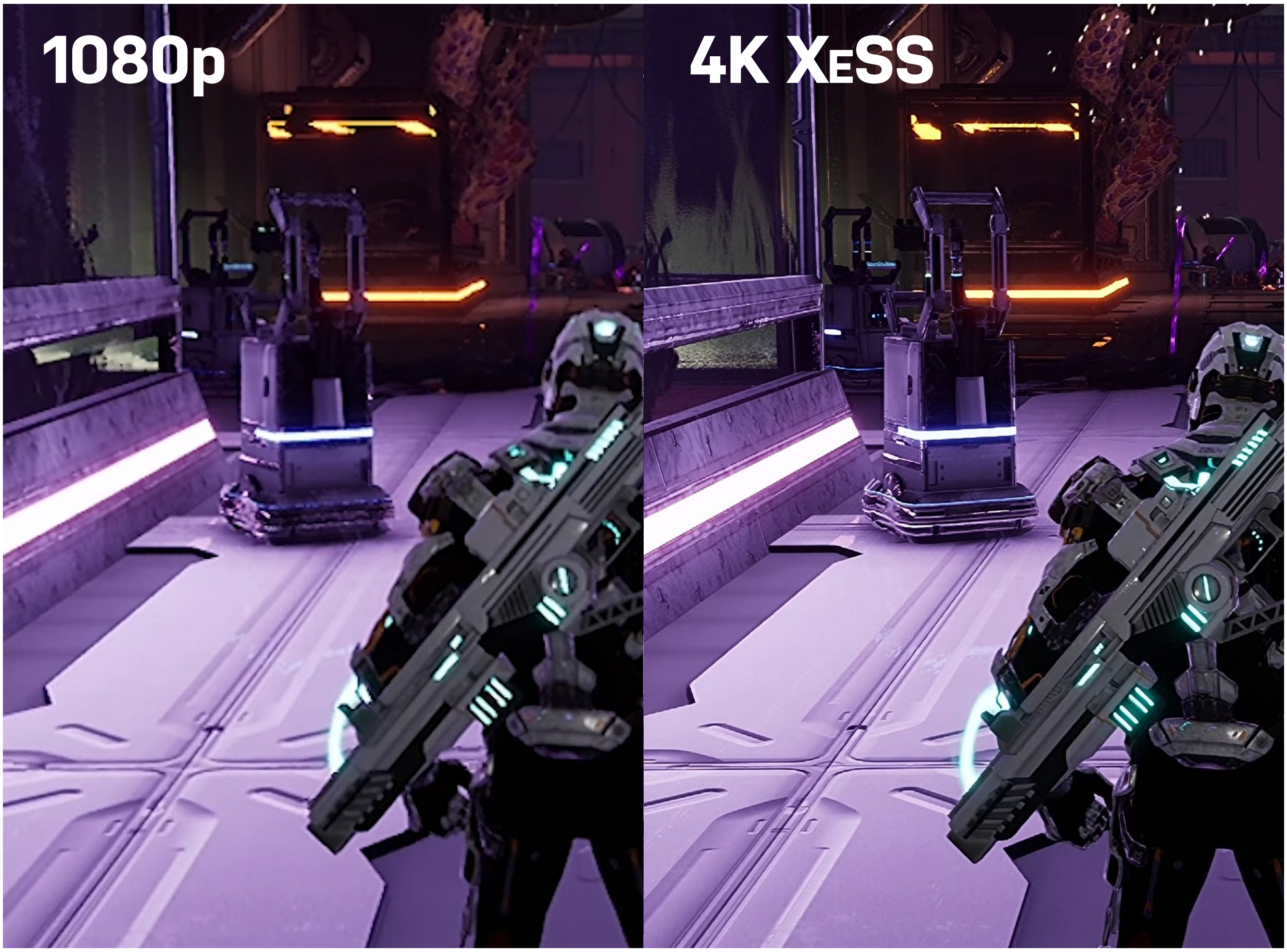

INTEL XeSS TAKES THE BLUE PILL

A preview of the native 1080p vs. 4K XeSS in *Dolmen*. The 1080p looks more like 540p, and what happened to the aquarium?

We had hoped to be able to provide some real-world commentary on Intel's contributions to the upscaling war. Unfortunately, the hardware and software are both still missing in action. Intel's Arc Alchemist GPUs are technically shipping in China, but early testing results indicate lots of driver bugs and other problems. XeSS meanwhile needs Arc GPUs to start shipping before it's likely to see any real use.

So far, we're aware of a few games that are supposed to support XeSS, like *Dolmen*, *Riftbreaker*, and *Hitman 3*. Much like the Arc hardware, the XeSS software support has been delayed. *Dolmen* was supposed to be the first out the door with XeSS support in May, but that was later changed to "this summer" and has yet to ship at the time of writing. That's probably because some of the early videos clearly showed some bugs in the XeSS upscaling. It doesn't help that critical reception of the game has been rather poor, with a Metacritic score of 54.

The core ideas behind XeSS sound nearly identical to DLSS. Train an AI algorithm using a supercomputer and millions of images of high-resolution 'target' images paired with low-resolution 'source' images. Given time, the algorithm will be able to take something like 1080p source content and upscale it into a decent looking 4K output stream. It will use temporal upscaling, receiving the current frame, data from the previous frame, the depth buffer, and a motion vector buffer.

Intel's Arc GPUs include MXM cores that are similar in practice to Nvidia's RTX tensor cores. They work with lower precision data and can crunch lots of numbers, perfect for handling a real-time upscaling algorithm. However, Intel has also said that XeSS will support an alternative mode using DP4a instructions (basically INT8), which means it would also run on Nvidia's Turing and newer GPUs and AMD's RDNA and newer GPUs. That made us hope for a 'best of all worlds' approach, but as the delays pile up and we still haven't seen a working demonstration of DP4a mode running on non-Intel hardware, we're becoming increasingly pessimistic about XeSS' chances.

© MICROSOFT

Deathloop supports both NVIDIA's DLSS and AMD's FSR 2.0 upscaling.

and it works well. It may only be available to a subset of gamers, but the latest Steam Hardware Survey suggests over a third of all Steam gamers now have an RTX card. That's a pretty sizeable chunk of the market, considering all AMD GPUs combined only account for 14 percent of surveyed PCs.

IN THE RED CORNER: AMD FSR

Like Nvidia, AMD now has two major variants of its FSR, or FidelityFX Super Resolution, upscaling algorithm. FSR 1.0 officially launched in June 2021, with an initial group of seven games. That number has climbed rapidly, and close to 100 games now support FSR. Unlike Nvidia, most FSR titles use the older (and easier to implement) FSR 1.0 with spatial upscaling, and only a handful of games are shipping with FSR 2.0 and its temporal upscaling. However, that's also partly because FSR 2.0 was only recently launched, in May 2022.

The core of the FSR 1.0 algorithm is a customized Lanczos filter with edge enhancement. That might seem like it's no big deal, and some have implied as much, but the edge enhancement and tuning do require some effort. AMD also had to build the API and tools around FSR that developers can use to get it working.

In testing, FSR 1.0 is lightweight, with about a five percent hit to performance, depending on the hardware, settings, and output resolution. FSR 1.0 has five modes: Ultra Quality, Quality, Balanced, Performance, and (optionally) Ultra Performance. Using the same calculation as Nvidia, those have 1.69X, 2.25X, 2.89X, 4.0X, and 9.0X upscaling factors.

Generally speaking, unless you have slow hardware, we would stick to Ultra Quality or Quality mode at most—the others have clearly visible losses in image fidelity.

After hearing complaints about the loss of image fidelity with FSR 1.0, AMD went back to the drawing board and, one year later, it released FSR 2.0 that's based on a temporal upscaling algorithm. That means it takes the same core inputs as DLSS 2.x—frame buffer, previous frame data, depth buffer, and motion vectors—but there's no AI-enhanced upscaling. Instead, it's a custom-created upscaling and anti-aliasing algorithm hand-tuned to generate 'desirable' results. In practice, FSR 2.0 looks much better than FSR 1.0 in the games we've tested, and it comes close to matching DLSS.

FSR 2.0 also uses the same Quality, Balanced, Performance, and optional Ultra Performance modes as DLSS, only dropping the Ultra Quality mode that was in FSR 1.0. Because the overall image fidelity has improved to such an extent, you can reasonably experiment with everything up to Performance mode and not get too distracted by artifacts, especially if you're playing at a resolution higher than 1080p.

Both variants of FSR have two major benefits over Nvidia's DLSS. First, they work on basically any modern GPU. We've tested them on everything from the latest AMD and Nvidia graphics cards down to integrated AMD and Intel graphics solutions. Performance might not be massively improved if you're trying to use FSR 2.0 on Intel UHD 770 Graphics, but it does work. Due to its smaller market share, AMD basically had to make FSR compatible with non-AMD GPUs, but it's still a great benefit. Even Nvidia users with GTX series graphics cards can thank AMD.

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DLSS GROWING PAINS

One of the difficulties with upscaling algorithms is getting the hardware and software in place to support the desired algorithm, while at the same time trying to create an optimal algorithm that can use the hardware properly. Nvidia did a lot of work with DLSS prior to the launch of its RTX 20-series GPUs, but ultimately a lot of that work ended up being wrong.

The first DLSS solution, DLSS 1.x, used a spatial upscaling approach and had to be trained on a per-game and per-resolution basis. The games required enormous effort by the developers and Nvidia to get DLSS working properly, with tens of thousands of images being sent to Nvidia's supercomputer for training purposes. It's hard to imagine Nvidia sustaining that approach over time and, thankfully, it found a better solution and released DLSS 2.x about a year after the first RTX cards began shipping.

This is the problem with creating something new. Everything might sound good on paper, but you have to crack some eggshells and fry up an omelet to find out how it tastes. DLSS sounded like a cool concept back in 2018 but tasted like a blurry and overhyped mess. It wasn't unusable, but *Battlefield V*, *Metro Exodus*, and the original *Shadow of the Tomb Raider* all had issues. And then in late 2019, *Control* came out and fixed many of the problems.

DLSS 2.0 and later no longer require per-game or per-resolution training. Instead, users get the now-familiar Quality, Balanced, and Performance modes. Games still need to be tuned to get the best results from DLSS, however. For example, the recently released PC version of *Spider-Man* had some rendering quality concerns with some pre-release code we were able to try, and further tuning of the DLSS implementation improved the image quality a lot. That's still a lot better than sending several terabytes worth of images over to Nvidia for processing.

Over 200 games and applications now have DLSS, with most opting to use the easier-to-implement and superior quality DLSS 2.x variant. Now FSR 2.0 and XeSS will need to play catch up.

Which came first, the Nvidia RTX 20-series Tensor core chicken or the DLSS algorithm egg?

The second big deal is that FSR is fully open source, which means game developers are free to modify the algorithms as they see fit. This also means if you can understand the code, you can see precisely what AMD is doing—there are no black boxes or secrets with FSR. Think you can do better than AMD's engineers when it comes to upscaling algorithms? Feel free to give it a shot. Of course, this means competitors can also learn how FSR works and potentially 'borrow' some ideas, but AMD doesn't appear to be concerned with that.

WHICH UPSCALER LOOKS BEST?

There's no good way to provide tons of screenshots and videos comparing the various upscaling solutions in the pages of a magazine. But what we can do is provide our impressions about how the various upscalers work, and what you can expect in terms of performance and image fidelity.

Nvidia DLSS ultimately wins in our head-to-head comparisons, though the number of games that support both DLSS and FSR, and particularly FSR 2.0, is quite limited. For the best image quality overall, you'll want an RTX graphics card. That also gives you the ability to use FSR 1.0/2.0 in games that support those, which means Nvidia RTX cards get to trump everything else in terms of compatibility. While there might be minor differences between native rendering and DLSS Quality mode in terms of fidelity, in motion the changes are so minor that we almost always enable DLSS Quality mode when it's available.

As you might expect, the benefits of DLSS can vary greatly depending on the game you're playing. The more demanding the graphics rendering engine, the more DLSS will help. Even using Quality mode, with a demanding game like *Cyberpunk 2077* running maxed-out ray-tracing settings, you can see a 50 percent bump in frame rates. On the other hand, games that don't use ray tracing don't benefit as much. *Red Dead Redemption 2* so far represents the smallest gains from DLSS, with Quality mode only improving performance by 10–15 percent.

AMD's FSR 2.0 is the next best choice and, if you don't have an RTX card, it's what you should want games to support. It's still relatively young, so there aren't a ton of games with FSR 2.0 yet. Like DLSS, so far the gains in performance and the relative drop in fidelity are such that we just about always run with at least Quality mode enabled in games that support it.

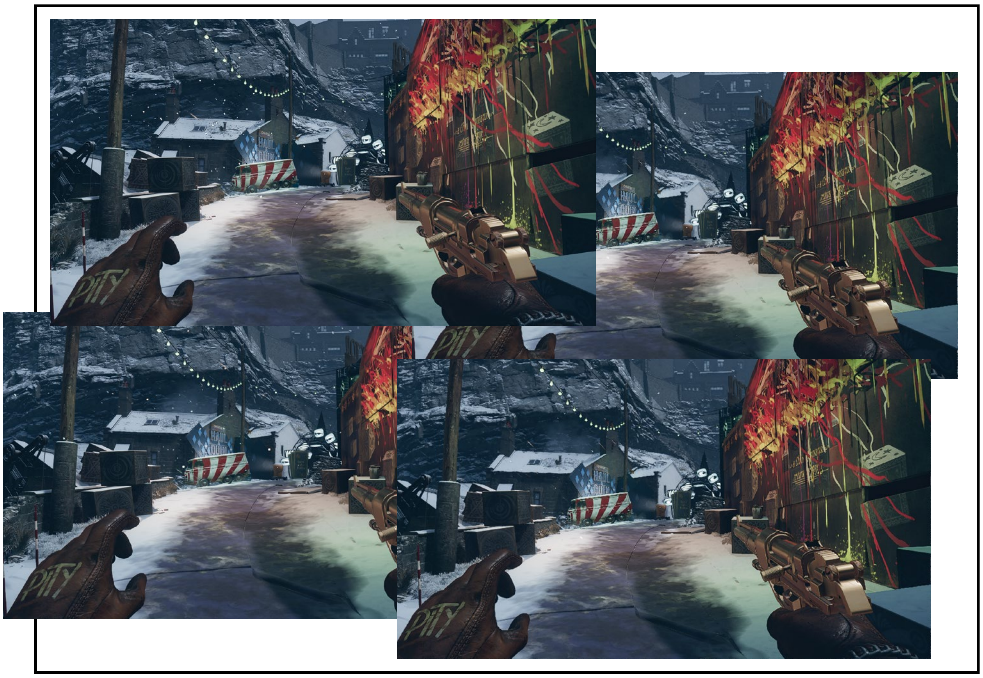
Upscaling is best tested by playing a game. If there is a boost in performance without a loss in fidelity, what more do you need to know?

If you do have an RTX card, the performance of DLSS also tends to be slightly better than FSR 2.0, meaning DLSS is still your best bet. The performance hit from FSR 2.0 is around 15 percent, give or take—meaning 1080p upscaled to 4K runs about 15 percent slower than native 1080p, but also looks better.

While we prefer DLSS and FSR 2.0, even getting FSR 1.0 support in a game is better than nothing. If you have a fast enough PC and graphics card, you don't need to use upscaling in the first place, but for those who might be lacking in hardware, having the option is nice. Ultra Quality mode provides a tangible bump in framerates if you just need a little nudge to get you above 60fps, and the upscaling artifacts are relatively benign.

Quality mode should be reserved for 1440p or 4K gaming, or those with seriously underpowered GPUs. Meanwhile, Balanced and Performance modes can boost your fps even more, maybe to the point where a game could break 144 fps, but the artifacts are visible.

As noted in the sidebar, Intel's XeSS hasn't actually come out for public use just yet. We'd love to see it work as well as DLSS, with the compatibility of FSR. Frankly, that's probably wishful thinking for the first iteration, but sign us up for XeSS 2.0.



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TO UPSCALE, OR NOT TO UPSCALE?

Maybe you already have an RTX 3090 Ti pumping pixels to your screen, and you don't feel much need for upscaling. But games continue to become increasingly demanding and if the metaverse ever truly takes off in Ready Player One fashion, we're definitely going to need ways for those without bottomless wallets to participate.

The great thing about upscaling is that it's optional—no one is forcing you to turn it on. If it's there and you think it works great, that's a win. If you hate it, no harm done. We'd rather have the setting and leave it off than not have the setting and want it.

Choice is one of the biggest benefits of PC gaming and PC hardware. We love to have

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Upscaling works best if applied to the rendered game world, leaving the user interface and text rendered at native resolution.

© ACTIVISION

PER-GAME INTEGRATION REQUIRED

FSR and DLSS are not 'universal' upscaling solutions that will simply work with whatever game or application you want. They require game developers to put in the effort to make the tools work. However, if you want upscaling with a game that doesn't support FSR or DLSS, there are alternatives from both companies—spatial upscaling options, naturally.

AMD's Radeon Image Scaling (RSR) uses the same core FSR algorithm but applies it to everything at a driver level. That means you can use it with pretty much any game or application. Upscaling artifacts might be more apparent when going down this route, but if you have a game that doesn't reach acceptable performance levels, it's worth a shot. Nvidia Image Scaling (NIS) is the same driver-based solution, although the upscaling algorithms are different—though Nvidia claims the results are comparable.

Why do FSR and DLSS require game developers to do extra work? DLSS and FSR 2.0 need access to more data and buffers, which they can't get from just the frame buffer. It enables them to generate overall more pleasing results. Game developer integration also allows the game to render the user interface and other elements like text at native resolution. It's amazing how much a clear UI and text can do to make you forget there's upscaling happening on the rest of the visuals.

Note that because of their input requirements—previous frame, depth buffer, and motion vectors—there's no easy way to make FSR 2.0 or DLSS into a universal, driver-level upscaling solution. Sorry!

options, for our CPUs, GPUs, cases, keyboards, mice, and even APIs. Unfortunately, unless game developers—and Nvidia, AMD, and perhaps Intel—start to become more open in their approach, our main choice for any single game will likely be whether to enable or disable just one of the upscaling solutions. There are already games that support both DLSS and FSR, but they're the exception rather than the rule. Anecdotally, it also seems like Nvidia is far more willing to attempt to convince game developers to pass on FSR.

That might change in the coming months, however. Nvidia talked about a new Streamline API that it's creating to allow game developers to potentially plug and play multiple upscaling algorithms.

Whether Streamline takes off or not, we hope something like it will become ubiquitous, because we'd love to be able to choose between DLSS, FSR 1.0, FSR 2.0, XeSS, or some other custom upscaling algorithm in the future. Until we reach the point where there's one upscaler that rises to rule them all—and unites the pixels behind them—that's our best hope. ⏻

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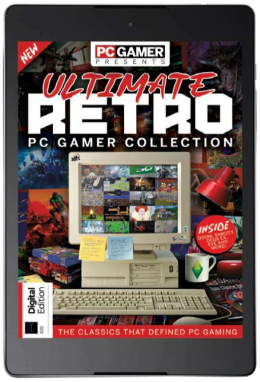
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SK hynix
PLATINUM P41 NVMe

THE FUTURE OF STORAGE

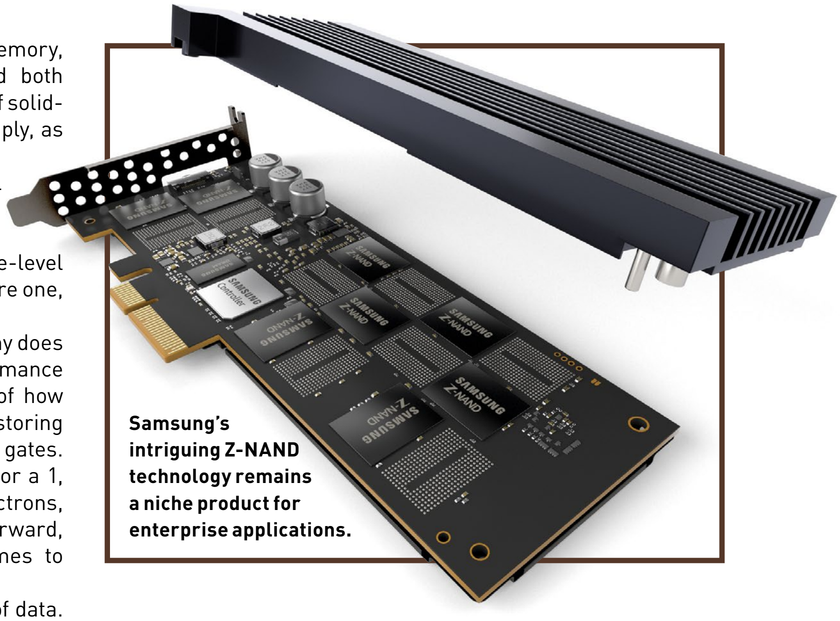
As SSDs get faster and cheaper, *Jeremy Laird* investigates how much more flash memory has to give and whether something better is around the corner

WHEN THE FIRST SOLID-STATE DRIVES (SSDs) for consumers appeared in 2008, it seemed like the problem of PC storage had been cracked for good. Finally, a fully solid-state PC was possible. On paper, even those early SSDs obliterated conventional hard drives with spinning magnetic platters when it came to most measures of performance.

But almost immediately it also became clear that the SSD was a work in progress. With a bit of use, early drives quickly became stuttering, laggy, useless bricks. More gradually, we PC enthusiasts became familiar with the inherent shortcomings of the predominant memory technology used for SSDs, namely NAND flash.

Since then, flash-based SSDs have improved beyond all recognition in terms of performance. At the same time, prices have fallen dramatically to the point where it's now routine to have a purely solid-state storage solution in a PC. Even high-performance 1TB SSDs can now be had for a little over $100 while $50 will buy you a serviceable budget model. That's pretty incredible.

That progress is set to continue for the foreseeable future as NAND flash memory is further refined. Faster, larger, and cheaper SSDs are pretty much guaranteed. Despite that, hope for a radical new technology that sidesteps the latency and endurance shortcomings of flash memory remains. Could a radical new approach to non-volatile memory be around the corner? Or is funked-up flash memory the future? Time to find out.



Samsung's intriguing Z-NAND technology remains a niche product for enterprise applications.

WHEN IT COMES TO solid-state storage based on flash memory, it's all about the trade-off between data density and both performance and endurance. Those three major metrics of solid-state storage prowess are intimately interlinked. Put simply, as density increases, performance and endurance fall away.

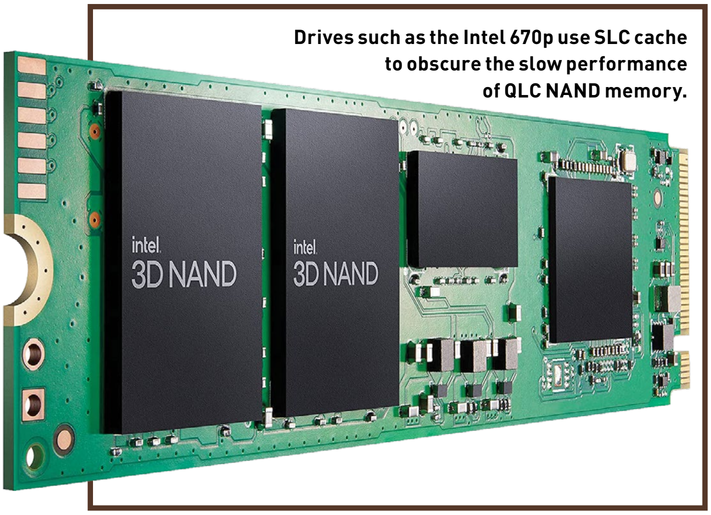
That's a bit of a pain but it all comes down to the cell structure of NAND flash memory. Currently, there are four commercially available varieties of NAND flash, SLC or single-level cell, MLC or multi-level cell, TLC or triple-level cell, and QLC or quad-level cell. Respectively, they can store one, two, three, and four bits of data per memory cell.

So far, so relatively simple. But the question follows, why does adding more cell levels or bits of data degrade both performance and endurance? To understand that, we need a grasp of how flash memory cells work. In basic terms, that involves storing an electric charge in the form of electrons between two gates. In a single-level cell (SLC), the cell is storing either a 0 or a 1, represented by the presence or absence of charge or electrons, also known as a reference voltage. That's pretty straightforward, both conceptually and in practical terms when it comes to measuring the presence or absence of charge.

As we've seen, MLC memory cells can store two bits of data. Thus an MLC cell can be in one of four states, namely '00', '01', '10', and '11'. In turn, that requires four different reference voltages or levels of cell charge to differentiate the four possible states. TLC or triple-level cells can store three bits of data—'000', '001', '011', and so on—which therefore dictates eight different cell states and requires eight reference voltages. Meanwhile, quad-level cells need 16 reference voltages to store their four bits of data.

It's obvious that as cell densities increase, so does the complexity. And then some. The critical point is that it's much easier to determine whether a cell simply contains charge or does not than it is to differentiate between 16 different levels of charge. As data density increases, errors inevitably creep in. Consequently, the workload in terms of comparison of charge states and the requirement for error correction increases exponentially with cell density. That's why performance takes a hit as cell density increases. It takes time to do all that work.

As for endurance, that hinges on the oxide layer in those aforementioned charge-storing gates. The oxide layer provides electrical insulation for the floating gate in a flash memory cell. Apply a sufficient voltage and the electrons will tunnel through the layer. But as they do so, they damage the oxide layer slightly. As the damage builds, the rate of errors during the write process increases. Eventually, the error correction algorithms used by SSD controller chips can't keep up with the errors, and the cell becomes unreliable.



Drives such as the Intel 670p use SLC cache to obscure the slow performance of QLC NAND memory.

That general principle applies to all flash memory cells regardless of the number of bits they can store. The problem with multi-level cells is that they store more bits per cell. So, each cell is written to more often and wears out faster. Real-world performance and endurance vary across different vendors and generations of NAND flash. But as a rule of thumb, SLC cells can be written to around 100,000 times, a process also known as a program-erase cycle, before wearing out, MLC can handle 10,000 cycles, TLC is good for 3,000 cycles, and QLC around 1,000 cycles.

Ostensibly, those figures look pretty horrifying for QLC memory in particular. In practice, it doesn't quite work out that way. Not that there are really any pure SLC consumer SSDs to buy these days, but if there were, they wouldn't necessarily have 100 times better endurance. And even if they did, it arguably wouldn't matter. Primarily, that's because modern SSDs have several technologies that effectively extend endurance, most notably wear leveling, which ensures data is written as evenly as possible across the drive, rather than hammering the same cells over and over until they fail.

The use of 3D layered NAND, as opposed to old-school 2D planar NAND, helps too. By stacking layers of cells vertically to increase density, the individual size of the cells becomes less critical. Current 3D flash has hundreds of layers of cells stacked on top of one another. That allows for larger individual cells while still increasing data density. And large cells are more resistant to write wear. Hold that thought, we'll come back to the question of 3D memory in a moment.

First, take the Samsung 870 QVO as an example of a QLC-based SSD. In 1TB format, the 870 QVO is rated at 370TB of write endurance. That's enough for 202GB of writes each day, every single day, for five years. More realistically, the vast majority of PC usage results in less than 50GB of write traffic daily. In other words, at least in terms of Samsung's claimed 370TB rating, it's unlikely that write endurance will be an issue for all but the most demanding users.

When it comes to performance, it's a little harder to pin down just how much performance drops off as cell densities increase. Partly, that's because pretty much all SSDs use multiple

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Micron is putting its cutting-edge 232-layer 3D NAND into its latest Crucial SSDs.

mitigations to obscure the underlying performance of the flash memory cells. The most important, arguably, is known as SLC caching. The idea is simple enough, namely running a portion of the available memory cells in faster SLC or single-level mode. Most modern drives allocate a dynamic amount of the available memory as SLC cache, depending on prevailing workloads.

Using the 2TB version of Intel's QLC-powered 670p M.2 SSD as an example, that drive offers a dynamic range of between 24GB and 280GB of memory running in SLC mode. Attempt to dump hundreds of gigabytes of data onto the drive and you'll find it achieves the claimed 3GB/s of sequential throughput for around the first 280GB of transfer. At that point, the SLC cache is exhausted and the underlying performance of the QLC flash memory is exposed. Performance then drops to a range between 250MB/s and 400MB/s.

Of course, the larger the SSD, the bigger the SLC cache. The 4TB version of Sabrent's Rocket Q4, another QLC drive, offers as much as 1TB of memory running in SLC mode. That allows for an awful lot of traffic before the true performance of its QLC memory cells is exposed. All of which is, inevitably, a long introduction to the questions that have been loitering just out of view. What comes next after QLC memory and could it be so slow and so short-lived in endurance terms that it's not actually viable for real-world usage?

At first glance, flash memory capable of storing five bits per cell, known as penta-level cells or PLC, seems like a non-starter. If 16 reference voltages are problematic in QLC memory, surely the 32 levels required for PLC will absolutely batter performance and endurance in return for marginal gains in density? After all, you're only gaining 25 percent in terms of data density going from four to five bits per cell, but the charge level complexity is doubling from 16 to 32. Could PLC memory be a step too far in terms of diminishing returns?

Certainly, the flash memory industry has gone quiet on PLC NAND memory of late. Back in 2019, Toshiba announced that it had PLC NAND test chips up and running. Late in 2020, Intel said it was on track to deliver PLC memory, too, and claimed that the technology will mean that SSDs finally hit sufficiently low cost per GB to replace old school hard disks for all mass storage. But here we are in late 2022, and there's no sign of either company releasing PLC memory chips and Intel is now in the process of offloading its entire SSD business to SK Hynix.

WHATEVER HAPPENED TO INTEL'S OPTANE TECHNOLOGY? IT WAS ALL SO PROMISING…

It was once the future of computer memory. A technology that promised to be as fast as RAM and more durable than flash memory. Now it's all but dead, so whatever happened to Intel Optane?

Based on a new non-volatile memory technology known as 3D XPoint, Optane-branded drives could maintain data storage without power. But like RAM, 3D XPoint memory was addressable at the bit level. That gave it much higher IOPS performance than any flash-based technology and much lower latency. 3D Xpoint also offers spectacular endurance. For example, the 1.6TB version of the Intel Optane SSD DC P5800X delivers a ridiculous 292PB (yes, petabytes!) of write endurance. Put simply, you won't ever wear that out.

It's all the more remarkable, then, how quickly the whole project failed. 3D XPoint technology was announced in 2015 with the first Optane drives going on sale in 2017. But by late 2018, Intel and its technology partner in 3D XPoint, Micron, had already decided to part ways and dismantle the joint venture. Intel canceled its Optane drives for consumers in January 2021 and in July this year, Intel decided to entirely wind down its Optane business. Meanwhile, in March 2021 Micron confirmed that it had ceased development of 3D XPoint technology and was selling the Lehi fab used to produce Optane chips.

While it's not impossible even at this late stage that another outfit may acquire 3D XPoint in some form, it certainly looks unlikely. As far as anyone can tell, Optane and 3D XPoint are toast. But why? The simple answer is money. According to figures from Intel's official 10K SEC filing, the Optane division lost $500 million in 2020, with 2021 thought to have generated a similarly large hole in Intel's balance sheet. It turns out that 3D XPoint memory chips were incredibly expensive to manufacture, to the point that even at the elevated prices Optane drives were selling compared to conventional SSDs, they were being marketed at a large loss. And still, they didn't really sell.

What's more, with Intel's revenues down a hefty 22 percent year-on-year in its most recent operating quarter, it's likely that the company simply couldn't stomach large losses from a subsidiary division that wasn't central to its plans for recovery. So Optane is a goner. And that's almost certainly for good.

intel
OPTANE

Intel's Optane tech promised so much, but simply proved too expensive.

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KIOXIA
FL6
BiCS FLASH™
KIOXIA XL-FLASH
Enterprise
NVMe™ SSD

Toshiba subsidiary Kioxia offers SSDs based on its low-latency XL-FLASH, but they're seriously expensive.

An arguably more realistic time frame for the arrival of PLC tech comes from Western Digital. Last year, WD predicted that PLC memory wouldn't hit the market until the latter half of the current decade. A major reason for that is allowing time for SSD controller chips to acquire the performance required to support the extremely demanding error correction that will be necessary to support PLC memory. ARM has already released its next-gen Cortex-R82 core for SSD controllers. It's twice as fast as the previous Cortex-R8 SSD-optimized design and also doubles in maximum core count from four to eight.

SSD controller chips based on Cortex-R82 should be quick enough for PLC NAND and are expected to start appearing in late 2023. However, the first chips will be quite large and expensive, which rather defeats the object of PLC memory in bringing the cost of storage down. For that reason, it's likely that PLC will only become viable once performant controller chips have been made affordable courtesy of a couple of die shrinks. We're not expecting to see PLC drives in our PCs, therefore, until around 2028. It really is that far out.

Of course, bit levels aren't the only way to increase memory density. The other major available route is by increasing the number of layers in 3D NAND, literally stacking memory cells on top of each other. Of course, 3D NAND now dominates the industry. And it is developments in this area that are likely to not only deliver consumer SSD capacity increases but also drive performance gains.

The current state of the art in terms of layering memory cells is Micron's 232-layer TLC NAND, which has just begun shipping as we go to press. Micron reckons its new 232-layer TLC chips are capable of 2.4GT/s I/O performance, 50 percent more than its previous 176-layer technology, along with twice the write and 75 percent higher read bandwidth. The 232-layer chips also achieve a much higher data density of 14.6 Gb/mm2, up 43 percent from the 10.3Gbit/mm2 of the 176-layer generation. The improved density has allowed Micron to finally produce its first 1Tbit TLC die. That in turn means that 2TB chip packages are possible by stacking 16 of their 232-layer dies. That's in a chip package smaller than a postage stamp. Remarkable.

COMPUTATIONAL SSDs ARE "SMART" SSDs THE FUTURE?

Storage devices that do their own computation—now there's an interesting idea. Not only could you reduce the overall load on the CPU, freeing up resources for other tasks. The flow of data back and forth between storage and the CPU could also be minimized.

If nothing else, data transfers use up a lot of energy. ARM estimates that over 60 percent of the energy consumed in computing gets hoovered up just moving data in and out of storage. And energy consumption is becoming an ever more sensitive issue for a whole range of reasons. So, what if you did the computation on the drive itself and didn't have to move the data over to the CPU at all? Not only would you save power, but as you add drives, you add performance. It's all win, win, right?

So far, this concept has largely been reserved for enterprise applications. Micron first mooted the idea back in 2013, modifying its mainstream M500 SSD with an ARM processor that could search MySQL databases. Apparently, with enough of the drives installed in a server, the CPU load for such searches dropped from 100 percent to just one percent while roughly cutting power consumption in half. Impressive.

The idea has since gone from concept to reality. Samsung, for instance, is now on its second generation of retail-available computational storage devices, known as Samsung SmartSSD. More specialized computational SSDs are expected in the future, with dedicated hardware for tasks such as encryption and video encoding and streaming.

Such drives would mean large installations of numerous expensive servers installed locally for delivering services like streaming video are no longer needed. Instead, you can have one or two servers and a stack of much cheaper computational SSDs.

All of which begs the question of how this might apply to client PCs. Software support is obviously key and, for now, that's restricted to enterprise applications. What's more, power consumption, even in the current context of an energy crisis, isn't an absolutely critical factor for desktop PCs. But for laptops and tablets? Now there's an application where dramatic reductions in power consumption could come in handy when it comes to battery life. Actually, we're surprised that computational SSDs for portable PCs aren't already a thing. One to watch for the near future? We think so.

crucial
M500
2.5-inch SOLID STATE DRIVE

Micron based an early computational SSD on its M500 SATA drive.

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WD_BLACK
SN850
GAME DRIVE
NVMe SSD

High-performance PCIe Gen 4 SSDs, such as the WD_Black SN850 pump out over 7GB/s of raw bandwidth.

SK Hynix's memory chip division, recently bolstered by acquiring Intel's flash memory business, is set to have its own 238-layer tech available next year and has rough plans for 500-layer memory in 2025 or 2026 and incredible 800-layer memory around 2030. Likewise, Micron and Samsung have roadmaps up to and including at least 500-layer flash memory laid out for the next few years.

Exactly how dense and how fast flash memory will be by the time it hits the 500-layer mark is a matter of speculation. However, if the gains Micron made with its latest 232-layer chips over 176-layer technology are at all indicative, 500-layer memory density and performance will be truly spectacular. Roughly, we'd expect SSDs capable of something around 30GB/s of raw bandwidth and offering around three times the capacity as today's drives to be available within four to five years. By the end of the decade, all bets are off. If 800-layer chips really are available, the speeds and densities are going to be bonkers.

If 3D NAND flash is likely to continue for the foreseeable future as the dominant storage technology, are there any alternatives on the horizon? Sadly, Intel's Optane drives are pretty much toast. You can read the boxout (on page 47) to find out more, but suffice to say, Optane is no longer a goer.

Right now, the only other remotely mainstream and available technology is in fact a derivative of NAND flash. The idea is to address the main weakness of flash memory, namely latency. To do that, both Samsung and Toshiba have taken a similar approach, which is based on a tweaked version of existing flash memory running in SLC or single-level cell mode. Samsung calls its take Z-NAND, while Toshiba's flash memory subsidiary Kioxia brands its technology as XL-FLASH.

Kioxia reckons its XL-FLASH reduces latency down to the 20µs to 5µs range—that's much better than today's typical high-performance TLC NAND memory, which is nearer 100µs. Though it's not as quick as Intel's defunct Optane tech, which in its final iteration was below 6µs. Samsung makes similar claims for its Z-NAND, pegging latency at around 20µs. Of course, thanks to running in SLC mode, both Z-NAND and XL-FLASH also offer much better endurance than the TLC and QLC flash memory used by consumer SSDs today. The problem, however, is that SLC memory is inherently less dense and so more expensive. That's probably why both Z-NAND and XL-FLASH remain niche products. It's also why they're unlikely to be the next big thing in consumer SSDs. Like Intel Optane, they're just too expensive.

However, there is one NAND derivative that looks more promising and it's known as X-NAND. The sales pitch from X-NAND's creator, a memory start-up founded in 2016 called NEO Semiconductor, is that it combines the data density and low cost of QLC memory with as good or even better performance than SLC flash. That is one heck of a claim.

NEO says X-NAND achieves this by reducing the size of flash memory page buffers by fully 94 percent. That matters because it enables the plane count in a flash memory die to be increased from two or four to as many as 64. If we've lost you at this point, a plane is a collection of NAND cells that can be read or written to in a single operation. Critically, these plane operations run in parallel. In other words, an X-NAND die can run 64 plane operations while conventional QLC NAND runs between two and four. Hey presto, that's a massive jump in I/O performance. All told, NEO claims X-NAND offers as much as 27 times the sequential read performance of existing QLC memory, 15 times the write performance, and around three times the random access performance.

X-NAND can also operate in SLC mode and offers similar performance benefits over SLC NAND as it does over QLC NAND when operating in QLC mode. In theory, that means you can have the choice of a big, cheap QLC drive that's as fast as an SLC drive without having to reduce capacity to allow for a large, fast SLC cache. Or you can have something exotic in terms of performance if you're willing to reduce capacity and run some SLC cache.

All very impressive. So what's the catch? Based on the most recent information we can find, NEO Semiconductor has a total of 10 employees and all of the above is theoretical. The chips don't actually exist. Instead, NEO is likely hoping to license X-NAND to one of the big boys in NAND manufacturing, such as Micron or Samsung. That said, NEO did win the Most Innovative Flash Memory Startup award at the 2020 Flash Memory Summit, so the industry is clearly impressed. But SSDs with X-NAND are several years away at minimum, if the technology does indeed ever deliver on the impressive promise.

Those NAND flash derivatives aside, the truth is that there is no obvious alternative to NAND on the horizon. Granted, there are numerous candidate technologies to be the next major

Early SSDs including the Intel X25-M quickly proved problematic.

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ROCKET Q4 NVMe 4.0
SABRENT
4TB
Developed by Sabrent in USA

A new technology known as X-NAND promises the density of QLC NAND similar to that of the Sabrent Rocket Q4 combined with the performance of SLC memory.

advance in non-volatile memory. Phase Change Memory (PCM), Resistance RAM (ReRAM), Ferroelectric RAM (FRAM), Magnetic RAM (MRAM), and Spin Transfer Torque MRAM (STT MRAM) are among the technologies that already exist and have some level of actual commercial availability. Looking further, carbon nanotube memory or NRAM is also under development.

However, none of these have moved out of niche enterprise applications into consumer products that you might be able to buy for your PC. The closest yet is Phase Change Memory courtesy of Intel's Optane SSD, which was fleetingly available for client PCs. Of the other candidate techs, the broad consensus is that Resistance RAM or ReRAM (sometimes also referred to as RRAM) is the most likely to succeed flash memory. It's another non-volatile memory tech that promises to solve the latency problem of NAND flash and also bit-level rather than page-level data addressing, which would dramatically improve performance. But thus far, not a single company has announced plans for a consumer ReRAM product, let alone launched one.

For at least the next three to four years, all the progress in PC storage will almost certainly be delivered by those more advanced 3D TLC chips with more and more layers, probably scaling to 500 layers toward the end of that time frame. As we've seen, that's not necessarily a bad thing. Yes, flash memory does have inherent limitations, especially when it comes to latency. But each new generation of 3D TLC technology will chip away at the latency limitations, improve performance and add capacity.

In that sense, flash memory is a bit like LCD technology in monitors and laptop displays. Conceptually, LCD is inherently a bad solution for a full-color motion picture display. It's transmissive, creating major problems in terms of contrast and viewing angles, while the need to physically move liquid crystals results in a poor response. But over the years, those technical limitations have been relentlessly refined to the point that, today, thanks to innovations, such as mini-LED backlights and pixel overdrive, the latest LCD panels are capable of incredible contrast and remarkable quick response.

Much the same applies to flash memory. It's fundamentally flawed but it's getting better all the time. So, yes, it is disappointing that Intel's Optane failed and that a low-latency alternative to flash memory has yet to emerge. But the short- to medium-term outlook for storage is still at least as promising in terms of progress, if not more so, than the likes of CPU or GPU tech. If larger, faster, and cheaper SSDs are a measure of that progress, there's plenty to look forward to. We guarantee it. ⏻

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PCI EXPRESS TRAIN

GEN 5 IS ALMOST ALIVE…

Remember the good old days of ribbon-like IDE cables, jumpers, and maximum bandwidth measuring 100MB/s? Back then, the introduction of SATA in 2003 was pretty dramatic stuff. It nearly doubled bandwidth, debuted a slick new physical connector, and even supported hot swapping.

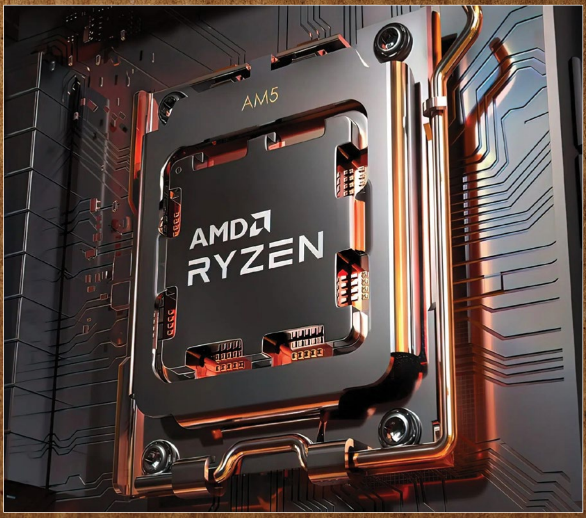
Pretty quickly, the theoretical peak bandwidth of SATA quadrupled to 750MB/s and storage performance was really up and running. Ever since then, that relentless progress has kept on coming. Today, the latest M.2 SSDs connect via a PCI Express 4.0 quad-lane interface supporting up to 8GB/s of bandwidth—more than RAM or system memory offered back when those IDE drives were being replaced by the first SATA HDDs.

Anyway, PCIe Gen 5 drives are already supported on Intel's latest 12th Gen Alder Lake CPUs, albeit with some limitations, and AMD is tooling up to add native PCIe Gen 5 M.2 storage support with its upcoming Ryzen, its new CPU family that could well have been announced by the time you read this. With PCIe Gen 5, theoretical throughput increases to a giddy 16GB/s for a quad-lane M.2 SSD, with real-world sequential performance in the region of 14GB/s.

That, of course, will not be the end of the story. PCIe Gen 6 will double performance once again, up to 32GB/s theoretical for an M.2 drive and the thick end of 30GB/s actual usable bandwidth. The full specification of PCIe Gen 6 was published earlier this year and the usual rule of thumb is that supporting hardware appears a year to 18 months later.

However, with PCIe Gen 5 SSDs only just about to hit the market, we suspect the delay could be a little longer, more like two to three years. Certainly, AMD won't have PCIe Gen 6 support until its Zen 5-based CPUs arrive.

As for Intel, we're not expecting either its next-generation Raptor Lake CPUs, due later this year, or Meteor Lake, due in 2023, to support PCIe 6.



AMD's Ryzen 7000 CPUs will be the first to offer native M.2 PCIe Gen 5 support.

BEST FREE SOFTWARE FOR VITAL PC TASKS

Some PC jobs are just too important to keep putting off, so you need to know the best programs to execute them correctly. *Nik Rawlinson* recommends 16 you should learn

WE ALL KNOW the kind of 'boring but useful' tasks we should carry out regularly on our computers: backing up, syncing, eradicating junk, and so on. Just as in life, there are lots of things we should do, but don't—but one of the reasons we put off such PC tasks is not knowing the best program to use. That's a problem we aim to fix in this feature.

We've highlighted 16 tasks you may have attempted in the past, perhaps with mixed results. We start with tools that help you manage your files: removing, renaming, searching for, and converting them. Once that's done, we move on to security—more specifically, encryption. You'll learn how to hide files behind passwords, and even inside other files.

Backing up and syncing are covered, followed by tools to keep your computer running smoothly: cleaning memory, analyzing hard drives, and uninstalling programs. We also recommend Wi-Fi programs for optimizing your network, including protecting your signal, before finishing with some handy tricks for your keyboard and mouse.

SOFTWARE WE RECOMMEND FOR EACH TASK

1.	TreeSize Free	www.snipca.com/42021
2.	Bulk Rename Utility	www.snipca.com/42022
3.	SearchMyFiles	www.snipca.com/42024
4.	Handbrake	www.snipca.com/42027
5.	VeraCrypt	www.snipca.com/42040
6.	OpenPuff	www.snipca.com/42041
7.	Synchredible	www.snipca.com/42053
8.	Folder2Iso	www.snipca.com/42052
9.	Mem Reduct	www.snipca.com/42059
10.	SeaTools	www.snipca.com/42061
11.	WhatInStartup	www.snipca.com/42062
12.	Acrylic Wi-Fi	www.snipca.com/42064
13.	Wireless Network Watcher	www.snipca.com/42076
14.	aText	www.snipca.com/42081
15.	SharpKeys	www.snipca.com/42082
16.	X-Mouse Button Control	www.snipca.com/42084

MANAGE YOUR FILES LIKE AN EXPERT

1 FIND AND REMOVE SPACE-HOGGING FILES

The excellent program TreeSize Free can help you find and delete files you've lost track of and have outlived their usefulness. Download the 'TreeSizeFree-Portable.zip' file from www.snipca.com/42021, unzip it, then right-click 'TreeSizeFree.exe' and choose 'Run as administrator' so it can scan folders that would otherwise be locked.

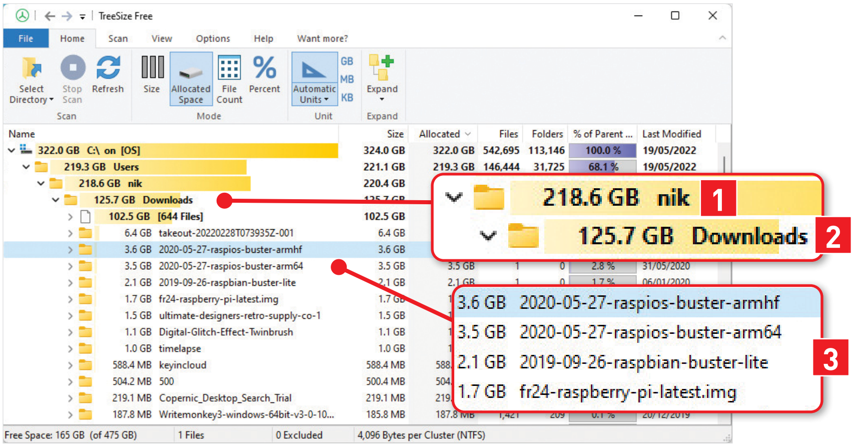
Click 'Select Directory', then 'This PC' in the File Explorer sidebar, followed by C:. Now click Select Folder, and TreeSize Free will scan your entire drive, and order your folders by size, with the largest first.

Much of what it finds will be Windows system files, so be careful what you remove. Expand the Users folder, and your own folder inside it, then explore the directories within. As you can see from the screenshot 1, we're working our way through the 'nik' user folder and have over 125GB of old files sitting in the Downloads folder 2, many of which can be removed.

This includes four versions of the Raspberry Pi operating system, occupying almost 11GB 3, that we installed several years ago. To delete a file, right-click it, then click Delete in the context menu.

Also, check the 'Program Files and 'Program Files (x86)' folders for particularly large sub-folders containing software you no longer use. Rather than delete these directly through TreeSize Free, though, you can uninstall them via Windows. In Windows 10, open Settings (press Windows key+I), then click Apps, followed by 'Apps & features' on the left. Now, in the middle pane, click an app you want to remove, then click Uninstall.

In Windows 11, click Apps, followed by Installed Apps, then click the three dots beside any you want to remove, followed by Uninstall.


TreeSize Free
File
Home
Scan
View
Options
Help
Want more?
Select Directory
Stop Scan
Refresh
Size
Allocated Space
File Count
Percent
Automatic Units
GB
MB
KB
Expand
Name
Size
Allocated
Files
Folders
% of Parent
Last Modified
322.0 GB C:\ on [OS]
219.3 GB Users
218.6 GB nik
125.7 GB Downloads
102.5 GB [644 Files]
6.4 GB takeout-20220228T073935Z-001
3.6 GB 2020-05-27-raspios-buster-armhf
3.5 GB 2020-05-27-raspios-buster-arm64
2.1 GB 2019-09-26-raspbian-buster-lite
1.7 GB fr24-raspberry-pi-latest.img
1.5 GB ultimate-designers-retro-supply-co-1
1.1 GB Digital-Glitch-Effect-Twinbrush
1.0 GB timelapse
588.4 MB keyincloud
504.2 MB 500
219.1 MB Copernic_Desktop_Search_Trial
187.8 MB Writemonkey3-windows-64bit-v3-0-10...
Free Space: 165 GB (of 475 GB)
1 Files
0 Excluded
4,096 Bytes per Cluster (NTFS)
1
2
3

TreeSize Free found 125GB of old files that we could safely remove.

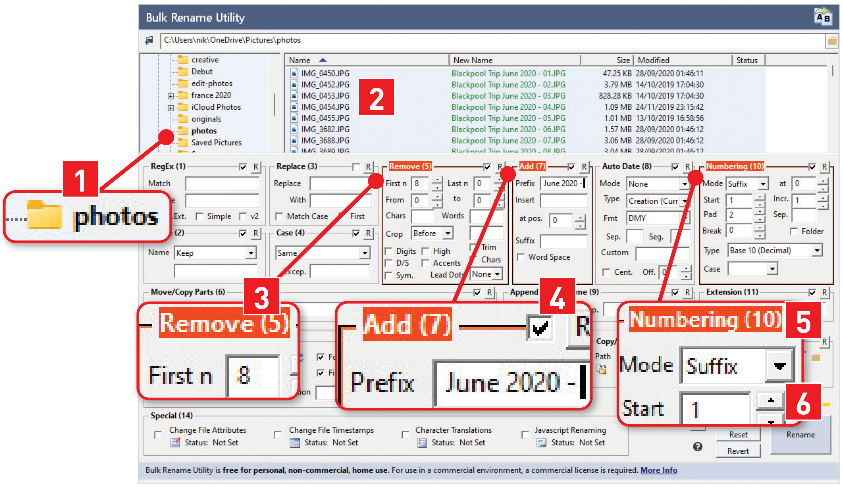
2 RENAME ALL YOUR FILES IN ONE GO

Your camera or smartphone labels every picture with a prefix and serial number. This ensures new pictures don't overwrite old ones, but does nothing to help you tell them apart. Renaming batches of pictures so they're more recognizable will help you search for them later.

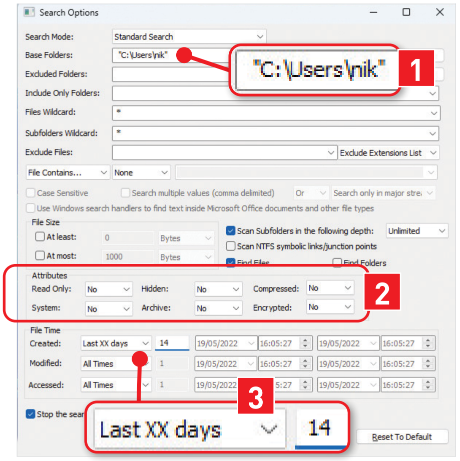
Install Bulk Rename Utility (www.snipca.com/42022), launch it, then in the top-left pane navigate to the folder containing the images you want to rename (1 in our screenshot below) Select these images in the main pane 2, then use the fields below to implement your changes. We're using the Remove option to strip out the first eight characters 3, which deletes everything before the '.JPG' file extension, then Add to prefix the new filename with 'Blackpool Trip June 2020 -' 4 and Numbering 5 to add a sequential number to the end of each file name 6. You can preview your changes in real-time in the main pane. When you've finished, click Rename to process your selected files.

3 SEARCH FOR MISSING FILES

When you've been working on a document but lost track of where you


Bulk Rename Utility
C:\Users\nik\OneDrive\Pictures\photos
Name
New Name
Size
Modified
Status
IMG_0450.JPG
IMG_0452.JPG
IMG_0453.JPG
IMG_0454.JPG
IMG_0455.JPG
IMG_3682.JPG
IMG_3688.JPG
Blackpool Trip June 2020 - 01.JPG
Blackpool Trip June 2020 - 02.JPG
Blackpool Trip June 2020 - 03.JPG
Blackpool Trip June 2020 - 04.JPG
Blackpool Trip June 2020 - 05.JPG
Blackpool Trip June 2020 - 06.JPG
Blackpool Trip June 2020 - 07.JPG
1 photos
2
3 Remove (5) First n 8
4 Add (7) Prefix June 2020 -
5 Numbering (10) Mode Suffix
6 Start 1
Rename
Bulk Rename Utility is free for personal, non-commercial, home use. For use in a commercial environment, a commercial license is required. More Info

Use Bulk Rename Utility to label your images in one batch and watch the changes happen.


Search Options
Search Mode: Standard Search
Base Folders: "C:\Users\nik"
Excluded Folders:
Include Only Folders:
Files Wildcard: *
Subfolders Wildcard: *
Exclude Files:
Attributes
File Time
Created: Last XX days 14
1 "C:\Users\nik"
2
3 Last XX days 14
Reset To Default

Tell SearchMyFiles where on your computer to look for missing files.

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saved it, you need to be able to search for it without using its name.

NirSoft's powerful SearchMyFiles (www.snipca.com/42024) does the job. When you run it, use the box that appears to tell the program as much as you can about the file you're looking for. In our screenshot below, we've told it to search our user folder **1** and selected 'No' for every option in the Attributes box **2**, so we don't get a huge list of system files. Finally, we know the file was created within the last two weeks, so we've specified 14 days in the File Time box **3**.

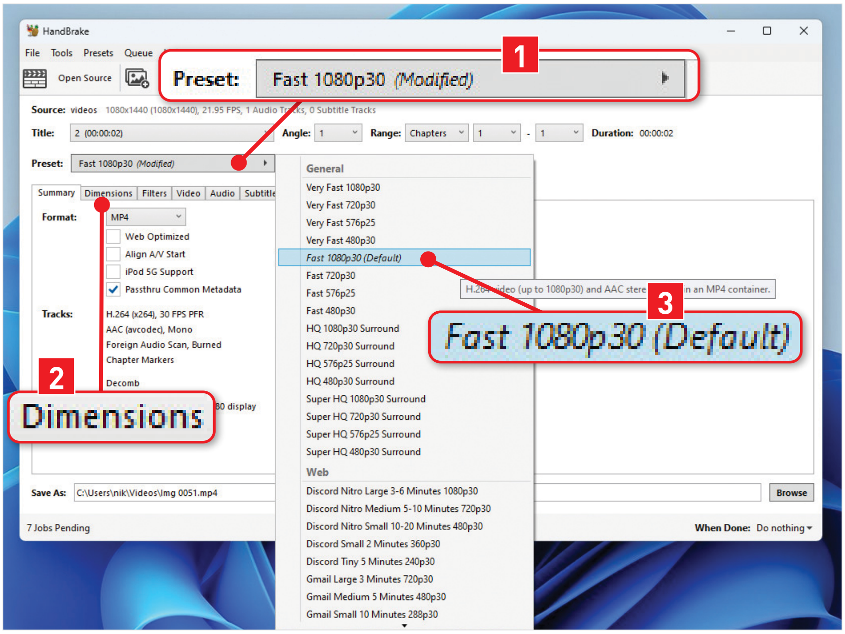
When you've given as much information as you can, click Start Search to scour your selected folders for your missing file.

4 CONVERT VIDEO FILES TO MODERN FORMATS

You should always make sure you convert your videos to modern formats because older formats will fall out of use, meaning you (and younger generations) won't be able to play them in the future. Handbrake (www.snipca.com/42027) lets you convert multiple videos simultaneously, saving you the time it would take to change the format of each video individually.

Collect your videos into a single folder, then launch the program and drag the folder onto the home screen to add its contents to a queue. Use the dropdown menu beside Preset (**1** in our screenshot) to select a format, and optionally click the Dimensions tab **2** to crop, add borders, and change resolution **3**.

When you've finished making your adjustments, press Alt+A to add the videos to the processing queue, then click Start Queue to encode them using your chosen settings. By default, they are saved in the Videos folder inside your User folder.


HandBrake
File Tools Presets Queue
Open Source
1
Preset: Fast 1080p30 (Modified)
2
Dimensions
3
Fast 1080p30 (Default)
General
Very Fast 1080p30
Very Fast 720p30
Very Fast 576p25
Very Fast 480p30
Fast 1080p30 (Default)
Fast 720p30
Fast 576p25
Fast 480p30
HQ 1080p30 Surround
HQ 720p30 Surround
HQ 576p25 Surround
HQ 480p30 Surround
Super HQ 1080p30 Surround
Super HQ 720p30 Surround
Super HQ 576p25 Surround
Super HQ 480p30 Surround
Web
Discord Nitro Large 3-6 Minutes 1080p30
Discord Nitro Medium 5-10 Minutes 720p30
Discord Nitro Small 10-20 Minutes 480p30
Discord Small 2 Minutes 360p30
Discord Tiny 5 Minutes 240p30
Gmail Large 3 Minutes 720p30
Gmail Medium 5 Minutes 480p30
Gmail Small 10 Minutes 288p30
Browse
7 Jobs Pending
When Done: Do nothing

Handbrake lets you choose a format, dimension, and resolution for a batch of videos.

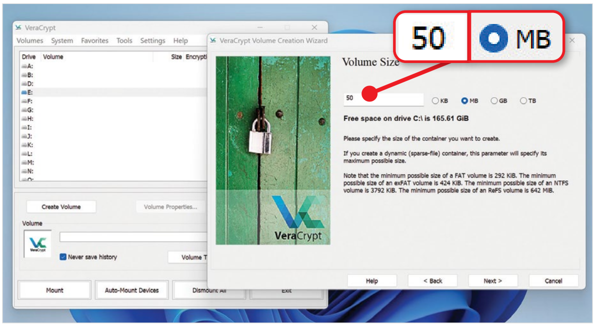
KEEP ALL YOUR FILES SECURE & PRIVATE

5 ENCRYPT A LOCKER OF FILES

Whether it contains personal finances or a list of passwords, there's nothing suspicious about encrypting a file to avoid disclosing its contents. Indeed, if you plan to email that file, encrypting it using a program like VeraCrypt (www.snipca.com/42040) is prudent. It scrambles files or folders using random algorithms, secured by a password.

Launch VeraCrypt, then select a drive letter in the top panel. It doesn't matter which one you choose because none of the options are used by any media attached to your computer—the letter is used to mount the encrypted locker you're about to create. Click 'Create Volume', then leave 'Create an encrypted file container' selected and click Next twice. When you reach the Volume Location screen, click 'Select File...', then navigate to the folder where you want to save your encrypted files. Type a name for the encrypted locker in the 'File name' box and click Save.

Click 'Next' twice, then specify how much space you'd like to devote to your locker. The more space you assign it, the more files you can store in it. If you're only going to encrypt a handful of documents, make your locker a little larger than their


50
MB
Volume Size
○ KB ● MB ○ GB ○ TB
Create Volume
Mount
Auto-Mount Devices
Help
< Back
Next >
Cancel
VeraCrypt

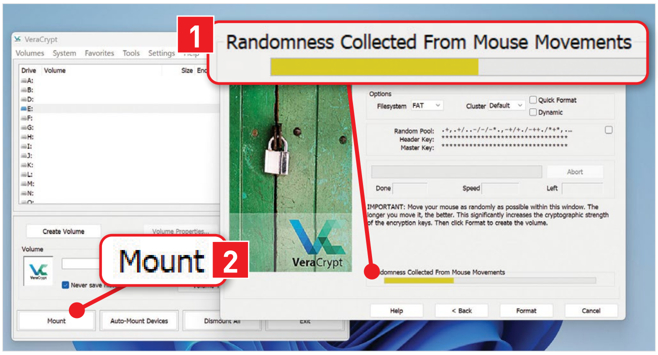
Free space on drive C:\ is 165.61 GiB

Please specify the size of the container you want to create.

If you create a dynamic (sparse-file) container, this parameter will specify its maximum possible size.

Note that the minimum possible size of a FAT volume is 292 KiB. The minimum possible size of an exFAT volume is 424 KiB. The minimum possible size of an NTFS volume is 3792 KiB. The minimum possible size of an ReFS volume is 642 MiB.

We devoted 50MB to our VeraCrypt locker containing a handful of Word documents.


1
Randomness Collected From Mouse Movements
2
Mount
Create Volume
Auto-Mount Devices
Options
Filesystem FAT
Cluster Default
☐ Quick Format
☐ Dynamic
Random Pool:
Header Key:
Master Key:
Abort
Done
Speed
Left
Help
< Back
Format
Cancel
VeraCrypt

IMPORTANT: Move your mouse as randomly as possible within this window. The longer you move it, the better. This significantly increases the cryptographic strength of the encryption keys. Then click Format to create the volume.

As VeraCrypt encrypts your file, you'll see the bar at the bottom fill up.

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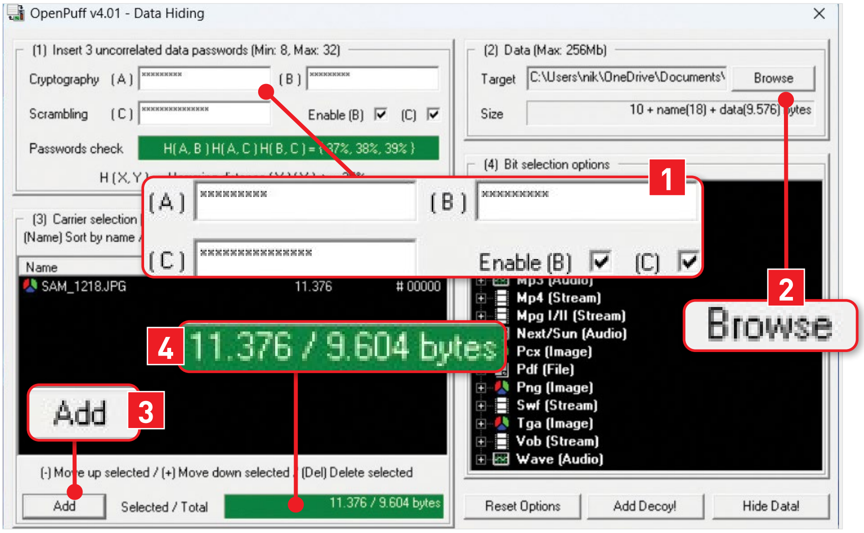
combined size. We're making a locker for some Word documents, so have only given it 50MB (see screenshot below left).

Click 'Next' and provide a password to encrypt and decrypt the locker. Click 'Next' again, then start moving your cursor randomly. This is what creates the algorithm that scrambles your file. When the bar at the bottom of the window is full (1 in our screenshot, below right), click Format. You'll be returned to the VeraCrypt home screen, with the drive letter you chose earlier still selected. Click 'Select File...', then navigate to and open the locker you just created, then click Mount 2. Enter the password you specified, then click OK.

Your encrypted locker will be unlocked and show up in Windows File Explorer, where it will behave like a regular drive. Drag the files and folders that you want to encrypt into it and, when you've finished, return to VeraCrypt and click Dismount. The locker will be removed from File Explorer, and can't be reopened without mounting it again and providing the password.


OpenPuff v4.01 - Data Hiding
(1) Insert 3 uncorrelated data passwords (Min: 8, Max: 32)
Cryptography (A)
(B)
Scrambling (C)
Enable (B) ☑ (C) ☑
Passwords check
H(A,B) H(A,C) H(B,C) = (37%, 38%, 39%)
(2) Data (Max: 256Mb)
Target C:\Users\nik\OneDrive\Documents\
Browse
Size 10 + name(18) + data(9.576) bytes
(4) Bit selection options
(3) Carrier selection
(Name) Sort by name
Name
SAM_1218.JPG 11.376 # 00000
Mp3 (Audio)
Mp4 (Stream)
Mpg I/II (Stream)
Next/Sun (Audio)
Pcx (Image)
Pdf (File)
Png (Image)
Swf (Stream)
Tga (Image)
Vob (Stream)
Wave (Audio)
(-) Move up selected / (+) Move down selected / (Del) Delete selected
Add
Selected / Total
11.376 / 9.604 bytes
Reset Options
Add Decoy!
Hide Data!
1
2
3
4

Enter three unrelated words as your password in OpenPuff, then select your file.

6 HIDE FILES INSIDE OTHER FILES

Steganography is a technique that lets you hide one file inside another—like a document inside an image. The image can still be opened, but only those who know there's another file hidden inside will be able to extract it and read its contents.

The tool you need to do this is called OpenPuff (www.snipca.com/42041—click 'Download binary for Windows/Linux' at the top of the page). Install and launch it, then click Hide on the first screen. Enter three unrelated words in the three boxes top left (1 in our screenshot) to create a password, then click Browse 2 and select the file you want to hide. Finally, click Add 3 and choose the image or images you want to hide your file inside. Your image(s) must be larger than the file you want to hide inside it. The red box at the bottom won't turn green 4 until you've chosen a large enough image, or added enough smaller images to accommodate your file.

Finally, click 'Hide Data!' and choose the folder where you want to save it. This way, OpenPuff can create a new copy of your image and its hidden contents, so the original won't be amended. The result can be opened for viewing, as an image, in a regular image viewer.

To extract your hidden file, launch OpenPuff again, but this time click Unhide on the first screen. Enter the same three words you used for your password, then click Add Carriers and select the output image (or images) created when hiding your file.

If you used more than one image, make sure you select them in the same order here. Now click 'Unhide!' and then specify where you would like the extracted file to be saved.

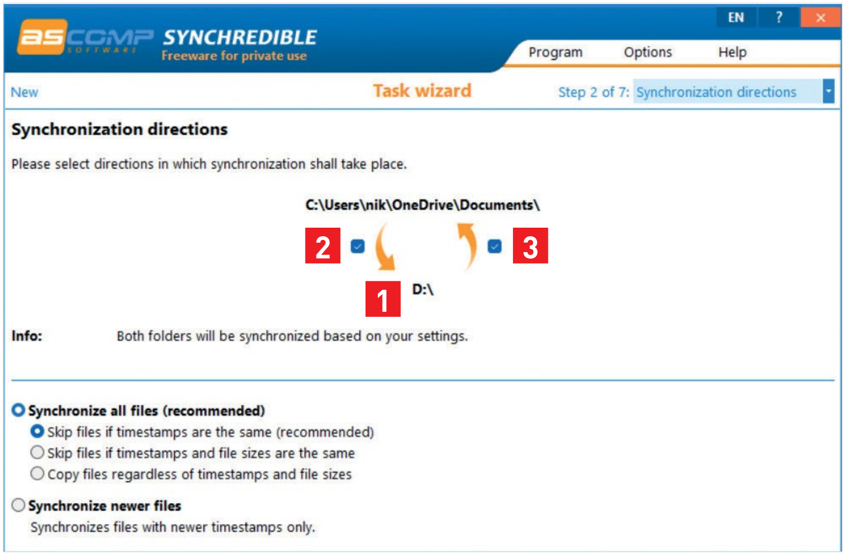
BACK UP & SYNCHRONIZE BETTER

7 SYNCHRONIZE YOUR FOLDERS

Synchronizing folders means you'll always have a current copy of the files you can take with you, should you need to work away from your main machine. You can set up synchronization using the free personal edition of Synchredible (www.snipca.com/42053).

Make sure your external drive is connected and, on the first screen, select the folder you want to back up by clicking the icon below Folder 1, and the folder to which you want to synchronize its contents by clicking the folder icon below Folder 2. We're synchronizing our Documents folder to an empty external drive, which is connected as D:(1 in our screenshot).

Click 'Next', then specify how the synchronization should be handled. You can sync from Folder 1 to Folder 2 by clicking the left-hand tick box 2. Here, any file you add to or delete from Folder 1 will


ASCOMP SOFTWARE
SYNCHREDIBLE
Freeware for private use
EN
?
Program
Options
Help
New
Task wizard
Step 2 of 7: Synchronization directions
1
2
3

Synchronization directions

Please select directions in which synchronization shall take place.

C:\Users\nik\OneDrive\Documents\

D:\

Info: Both folders will be synchronized based on your settings.

● Synchronize all files (recommended)
- ● Skip files if timestamps are the same (recommended)
- ○ Skip files if timestamps and file sizes are the same
- ○ Copy files regardless of timestamps and file sizes

○ Synchronize newer files
Synchronizes files with newer timestamps only.

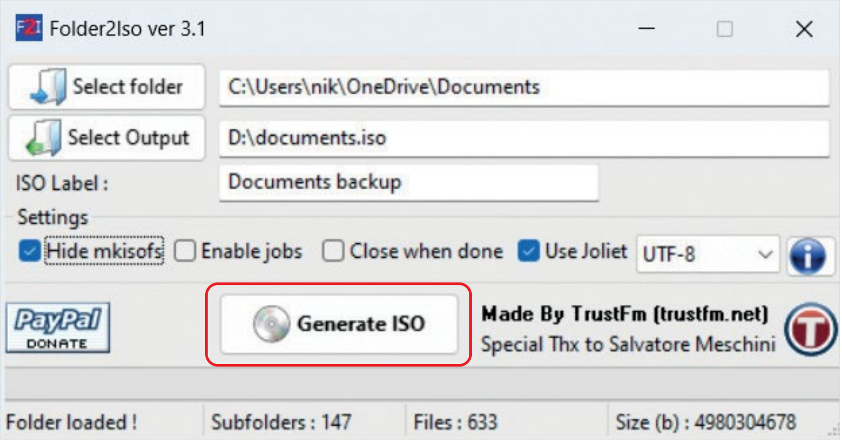
Either tick one box to sync in one direction, or both to keep them fully synchronized.

be added to or deleted from Folder 2, but anything you do to Folder 2 does not effect Folder 1. Ticking only the right-hand box 3 does the opposite, so the operations you perform on Folder 2 will be reflected in Folder 1. However, we want to keep the folders fully synchronized at all times, which is how online-storage services like Dropbox behave, so we tick both boxes.

Click 'Next' twice, then specify whether Synchredible should ignore any specified file types, such as large downloads that would quickly eat into your available space. Click the Exclude tab, followed by Add, then select 'Manual filter' in the dropdown menu. Specify the extension (such as *.iso to exclude all files with an iso extension) or folder (such as /backups/ for a backups folder inside Folder 1, if it exists) that you want to exclude.

Click 'Next' again, then expand the 'Synchronization on changes' section and tick the boxes beside both 'Synchronization on changes in folder 1' and 'Synchronization on changes in folder 2' boxes to enable real-time monitoring. Any amendments you make to your files will now be immediately reflected in the synchronized folder. Click 'Next' twice, followed by Apply.

Finally, click 'Execute task' to perform your first synchronization. This will take longer than subsequent syncs, which only copy across changes. Even so, our initial synchronization of 633 files was completed in two minutes. You can close the Synchredible window and the program will continue running in the background.



Folder2Iso ver 3.1

Select folder: C:\Users\nik\OneDrive\Documents

Select Output: D:\documents.iso

ISO Label : Documents backup

Settings

☑ Hide mkisofs ☐ Enable jobs ☐ Close when done ☑ Use Joliet UTF-8

Made By TrustFm (trustfm.net)
Special Thx to Salvatore Meschini

Folder loaded ! Subfolders : 147 Files : 633 Size (b) : 4980304678

Click 'Generate ISO' to save your files as an ISO using Folder2Iso.

8 BACK UP FILES AS ISOS

ISO files are virtual disks. Creating one when backing up a folder ensures its contents match the source when re-opened, complete with original sub-folder structure. You don't need special software to read an ISO, but you need a free program such as Folder2ISO to create one.

Click the OneDrive link halfway down the page at www.snipca.com/42052 to download Folder2Iso. Then double-click the file to expand it, then launch the 'Folder2Iso.exe' file from the /folder2iso/ folder inside your Downloads folder.

Click 'Select Folder' and choose the folder you want to back up, then click Select Output and navigate to the location where you want to save the ISO file. Give the ISO a name in the 'File name' box, and click Save.

Next, click 'Generate ISO' (see screenshot) and wait for the process to complete (it took around 20 seconds for the 633 files in our Documents folder), then check that it's made an accurate copy of your originals by navigating to the ISO file, double-clicking it, and selecting File Explorer when Windows asks how you want to open it. It should mount as a new drive (E: in our case), masquerading as a CD ROM.

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KEEP YOUR PC RUNNING SMOOTHLY

9 CLEAN UP PC MEMORY

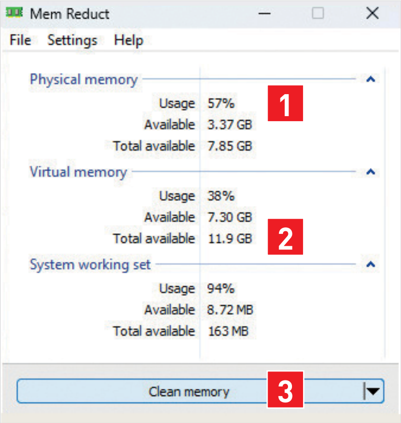
The quickest way to free up memory when you start running short is to reboot, but that requires you to quit every program and save your work. A better alternative is to use memory-cleaning software to work out which data your memory chips no longer need to retain and clear it out.

Mem Reduct does this by using features that are difficult for users to access. Visit www.snipca.com/42059 then click 'memreduct-3.4-setup.exe' to download. Once installed, it should launch automatically and show how much physical and virtual memory you have—and how much is free.

When we first ran Mem Reduct, we were using 57 percent of our 7.85GB of physical memory (1 in our screenshot above right), along with 38 percent of our 11.9GB of virtual memory 2. After clicking 'Clean memory' 3, the virtual memory figure remained the same, but the physical memory figure dropped to 25 percent. We recouped over 2.5GB of usable memory that our active programs could put to good use.

10 ANALYZE YOUR HARD DRIVE

As the place where you store all your photos and files, it's important to keep your hard drive healthy. SeaTools from Seagate works with any brand of hard drive or SSD and can help you to monitor its condition. Click 'SeaTools 5 (Windows)' in the Downloads section at www.snipca.com/42061 then work through the instructions.



Physical memory
Usage 57%
Available 3.37 GB
Total available 7.85 GB

Virtual memory
Usage 38%
Available 7.30 GB
Total available 11.9 GB

System working set
Usage 94%
Available 8.72 MB
Total available 163 MB

We were using 57 percent of our physical memory before running Mem Reduct.

Once up and running, you'll see a list of all the drives installed on your PC. Start by selecting the one you want to analyze, clicking Quick Tests (see screenshot below) under the Health tab, and picking Short Self Test. This tests all aspects of how the drive is working but doesn't perform any random tests on the read/write area itself. It took around three minutes to complete this test on our internal Intel NVMe SSD.

For a more thorough test, click Extended Tests and choose one of the options. The 'Long Drive Self Test' goes beyond the Short Self Test by performing limited checks of random sectors of the drive's data storage surfaces to check they aren't corrupted. The 'Long Generic Test' checks every sector, rather than just random areas, while the '2-minute Generic Test' limits the number of spots it checks to reduce the working time.

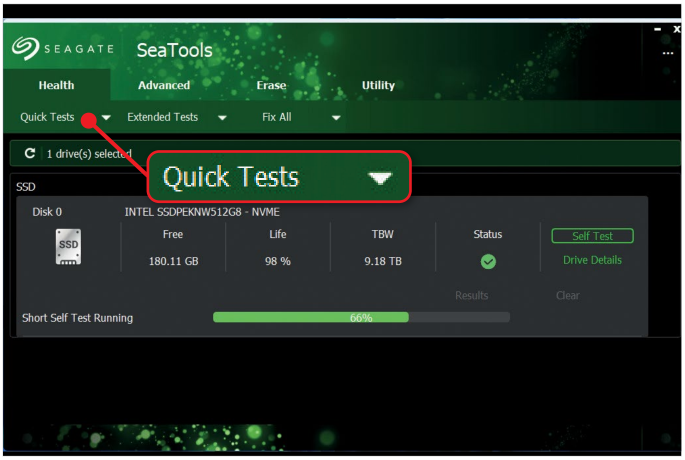
Should the tests reveal any problems, make a complete backup of your drive (or at least your User folder if you only want to secure your data and not programs) before exploring the Fix All menu, which has two options: Fix All Short and Fix All Long. Both perform a thorough check of every sector and carry out a fix or move the data to an alternative spot on the drive. The 'Fix All Long' option can't be interrupted and Seagate says it may take up to an hour per terabyte to complete.

11 DISABLE YOUR STARTUP ITEMS

Limiting the number of programs that run when your PC starts means your memory and processor capacity can be devoted more fully to the software you're actively using. It can also reduce the time it takes to get Windows ready for action.

WhatInStartup (www.snipca.com/42062) reveals which programs your PC runs automatically, and lets you switch them off. Select one you don't need and press F7 to disable it. As you can see from our screenshot below, we've disabled seven programs on our PC—highlighted in grey, with 'Yes' listed in the Disabled column.

You can easily re-enable a program by selecting it and then pressing F8. If you want to take more drastic action, press Ctrl+Del to remove a program from the startup list entirely. The software itself won't be deleted, but it will stop running when Windows starts.



1 drive(s) selected

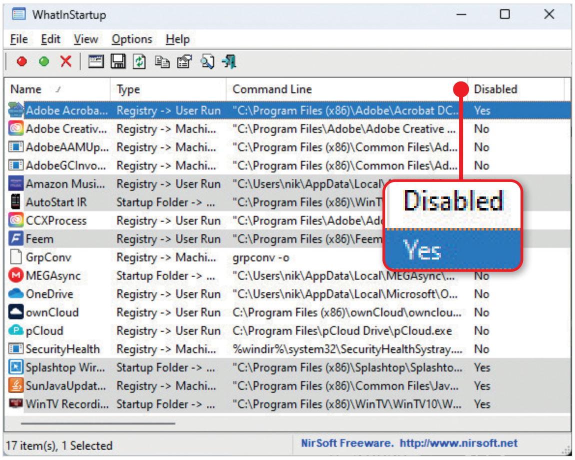
SSD

Disk 0 INTEL SSDPEKNW512G8 - NVME

Free	Life	TBW	Status
180.11 GB	98 %	9.18 TB	✓

Short Self Test Running 66%

SeaTools took three minutes to run the Short Self Test on our internal Intel NVMe SSD.



Name	Type	Command Line	Disabled
Adobe Acroba...	Registry -> User Run	"C:\Program Files (x86)\Adobe\Acrobat DC...	Yes
Adobe Creativ...	Registry -> Machi...	"C:\Program Files\Adobe\Adobe Creative ...	No
AdobeAAMUp...	Registry -> Machi...	"C:\Program Files (x86)\Common Files\Ad...	No
AdobeGCInvo...	Registry -> Machi...	"C:\Program Files (x86)\Common Files\Ad...	No
Amazon Musi...	Registry -> User Run	"C:\Users\nik\AppData\Local\	
AutoStart IR	Startup Folder -> ...	"C:\Program Files (x86)\WinT	
CCXProcess	Registry -> User Run	"C:\Program Files\Adobe\Ad	
Feem	Registry -> User Run	"C:\Program Files (x86)\Feem	
GrpConv	Registry -> Machi...	grpconv -o	
MEGAsync	Startup Folder -> ...	"C:\Users\nik\AppData\Local\MEGAsync\...	No
OneDrive	Registry -> User Run	"C:\Users\nik\AppData\Local\Microsoft\O...	No
ownCloud	Registry -> User Run	C:\Program Files (x86)\ownCloud\ownclou...	No
pCloud	Registry -> User Run	C:\Program Files\pCloud Drive\pCloud.exe	No
SecurityHealth	Registry -> Machi...	%windir%\system32\SecurityHealthSystray....	No
Splashtop Wir...	Startup Folder -> ...	"C:\Program Files (x86)\Splashtop\Splashto...	Yes
SunJavaUpdat...	Registry -> Machi...	"C:\Program Files (x86)\Common Files\Jav...	Yes
WinTV Recordi...	Startup Folder -> ...	"C:\Program Files (x86)\WinTV\WinTV10\W...	Yes

17 item(s), 1 Selected
NirSoft Freeware. http://www.nirsoft.net

Disable any program in WhatInStartup and it will be highlighted in grey.

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GET BETTER WI-FI AT HOME

12 CHOOSE THE RIGHT WI-FI NETWORK

Even the most basic of modern routers is capable of hosting two networks simultaneously. One usually runs at 2.4GHz, while the other runs at 5GHz—the former is slower but spreads further, and the latter provides better performance but degrades quicker as it passes through walls and floors. Choosing between them depends on where you use the connection more than the specs of the router.

When faced with the task of choosing the best network, you opt for the fastest option, but that's not always the right choice. A network's stated speed will be a measure of the maximum rate supported by the router, and you'll only ever see that kind of performance if the signal reaches your PC under optimal conditions. It will rarely do that (see page 25).

Acrylic Wi-Fi (www.snipca.com/42064—click 'Download for Windows' in the 'Free download' box to the left) helps you choose the best network to use in any location. It does this by visualizing not only its speed but also the quality of the signal at that location. When you've installed it, click Acrylic Wi-Fi Home from the list of options on the program's home page.

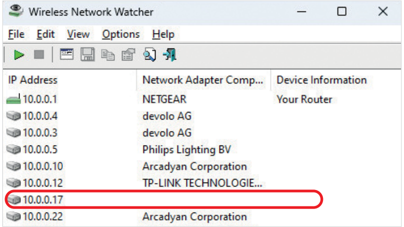
Click the Max Speed column header (**1** in our screenshot below) twice to order the networks with the fastest at the top. If it's one of your own, click it, and check the status bars and graph below to see how strong the signal is at your current location. Although we own both the Brecqhou-5G2 **2** and Ovingo **3** networks (and most of the others), we prefer not to use Brecqhou-5G2, despite it supporting a higher maximum speed, because the graph suggests average performance, while Signal Quality, in the status bars, is halfway between best and worst.

Ovingo, however, while supporting a lower maximum speed, has full bars for both Signal Quality and Transmission Speed **4** and a line that consistently cuts a higher path on the graph (see the green line **5**). The higher signal quality suggests we'll get a more reliable connection even though the theoretical maximum speed supported by that network is lower.

13 CHECK IF SOMEONE IS STEALING YOUR WI-FI

If your Wi-Fi feels sluggish, or you're on a capped broadband contract and frequently approach or exceed your bandwidth limit, an unauthorized device might have piggybacked onto your network.

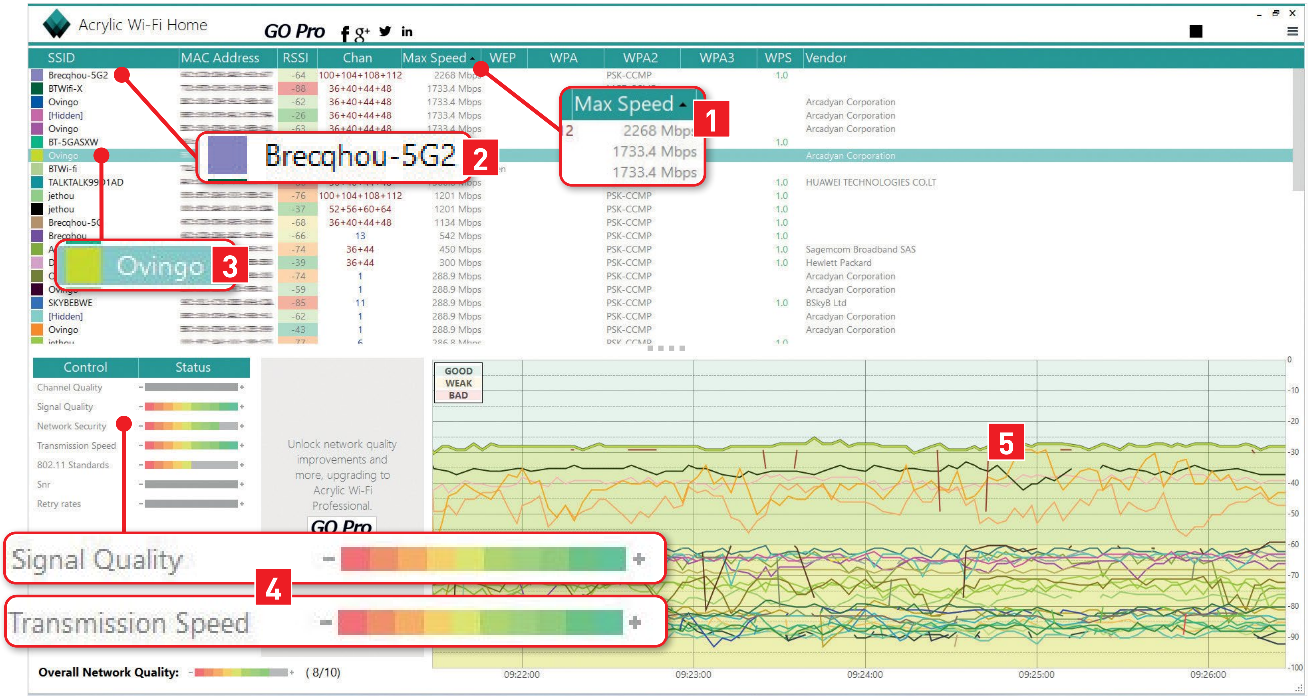
The simplest solution to this problem is to change your network password, via the router's configuration pages, but doing so disconnects all the devices you've authorized yourself—not just computers and tablets but also any 'smart' devices you have around the home. Reconnecting them can be a time-consuming business that you want to avoid if you can.


Wireless Network Watcher
File
Edit
View
Options
Help

IP Address	Network Adapter Comp...	Device Information
10.0.0.1	NETGEAR	Your Router
10.0.0.4	devolo AG	
10.0.0.3	devolo AG	
10.0.0.5	Philips Lighting BV	
10.0.0.10	Arcadyan Corporation	
10.0.0.12	TP-LINK TECHNOLOGIE...	
10.0.0.17		
10.0.0.22	Arcadyan Corporation	

We checked the unnamed device at 10.0.0.17 and discovered it was one of our Wi-Fi boosters.

NirSoft's Wireless Network Watcher (www.snipca.com/42076) lists all the devices connected to your router, so you can check them and avoid the hassle of changing your password. As well as device names, and details of who made the network adapter in each one, it shows their IP addresses, which sometimes link through to a configuration of information screen if typed into a browser. Where our network is hosting an unnamed device at 10.0.0.17 (see screenshot), for example, typing that into a browser leads us to the login screen for a wireless network booster that we know is ours. It's therefore not a threat and we can ignore it.


Acrylic Wi-Fi Home
GO Pro
SSID
MAC Address
RSSI
Chan
Max Speed
WEP
WPA
WPA2
WPA3
WPS
Vendor
Max Speed
1
Brecqhou-5G2
2
Ovingo
3
Control
Status
Channel Quality
Signal Quality
Network Security
Transmission Speed
802.11 Standards
Snr
Retry rates
Unlock network quality improvements and more, upgrading to Acrylic Wi-Fi Professional.
GO Pro
GOOD
WEAK
BAD
5
Signal Quality
4
Transmission Speed
Overall Network Quality:
(8/10)
09:22:00
09:23:00
09:24:00
09:25:00
09:26:00

We've chosen the Ovingo network because although the speed is lower, it is more reliable.

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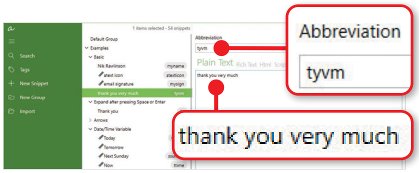
DO CLEVER THINGS WITH YOUR KEYBOARD & MOUSE



Use aText to create snippets you type to trigger longer phrases

14 TYPE LONG PHRASES INSTANTLY

How many times have you signed off an email with an identical turn of phrase? You can use aText (www.snipca.com/42081) to stop this from becoming tiresome by defining snippets that, when typed, are replaced by much longer phrases.

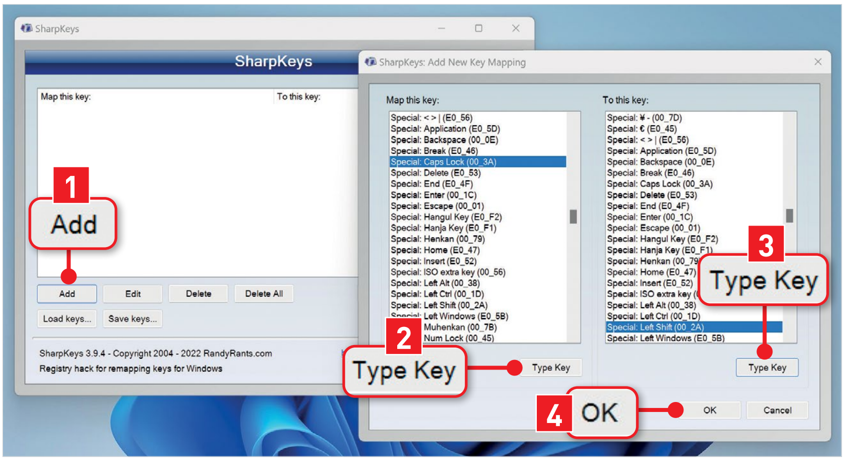
So, for example, to save you typing 'thank you very much' a dozen times a day, you could create a new snippet for that phrase and attach the abbreviation 'tyvm' (see screenshot above right). Every time you type `tyvm`, it is swapped for the complete sentence. You can create both plain text and rich text snippets—the latter can include images and formatting.

15 CHANGE WHAT CERTAIN KEYS DO

If your volume buttons have stopped working, or you want to disable the Caps Lock key so you don't hit it by accident when reaching for Shift, use SharpKeys to 'remap' your keyboard's behavior, changing what a certain key does.

Download it by clicking the 'sharpkeys394.msi' link at www.snipca.com/42082, then launch the file and work through the installer screens. Click 'Add' (**1** in our screenshot below) to remap your first key, then click Type Key **2** below the left-hand column and press the key you want to change. Now click Type Key below the right-hand column **3** and press the key you want it to emulate. Click OK **4**, followed by 'Write to Registry', then click OK, log out of Windows, and reboot your computer for your changes to take effect.

To return a button to its original function, open SharpKeys, select the changed key in the list on the opening screen and click Delete. Click 'Write to Registry' to save your changes, and reboot your machine for them to take effect.



SharpKeys lets you change what certain keys do when you press them.

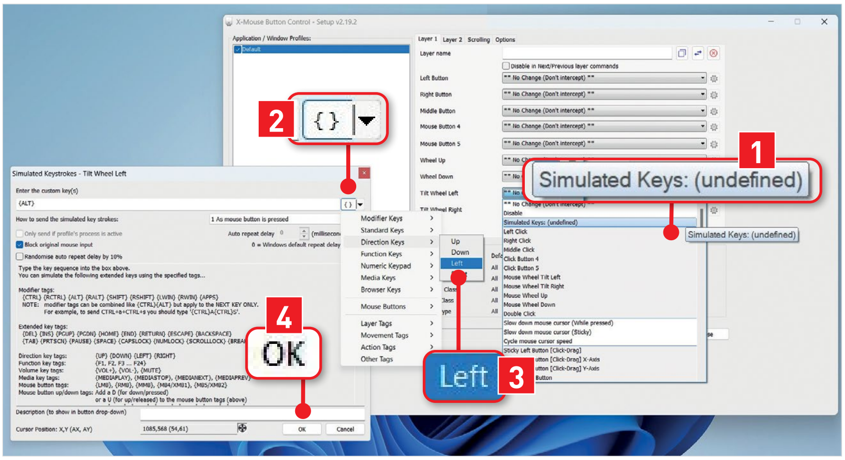
16 BROWSE THE WEB QUICKLY WITH YOUR MOUSE

If you're anything like us, your hand will rarely leave your mouse when browsing the web, even though common shortcuts like Alt+left and Alt+right can be used in many browsers for going back and forth through the browsing history of a tab.

X-Mouse Button Control (XMBC) can help here. We can use it to reprogram what happens when we press left or right on the scroll wheel of a tilting mouse. In our case, our laptop also emulates this function when we swipe left or right with two fingers on the trackpad. This depends on your laptop, so check your own trackpad to see whether it does the same.

Download XMBC by clicking the 'Latest version' link (top left) at www.snipca.com/42084. Open the download and work through the installer, leaving everything at its default setting. Now click the dropdown menu below Tilt Wheel Left and select 'Simulated Keys: (undefined)' (**1** in our screenshot below). Click the dropdown menu at the top right of the following screen **2**, hover over the Modifier Keys sub-menu, and click Alt on the menu that appears. Click the same button, hover over Direction Keys, then click Left **3**. Finally, click OK **4**. Windows will now interpret a sideways press to the left on the tilting mouse wheel as an Alt+left key combination.

Repeat the above process, this time for the dropdown menu below Tilt Wheel Right, and select Right when choosing a button from the Direction Keys menu. Click Apply. Test your new settings by opening a browser window and navigating to a page of your choice. Now tilt the central wheel of your mouse to the left to navigate back to the previous page. ⏻



We used XMBC to change the left- and right-clicks on the scroll wheel of a tilting mouse.

GET READY TO BECOME A TRUE PYTHON EXPERT

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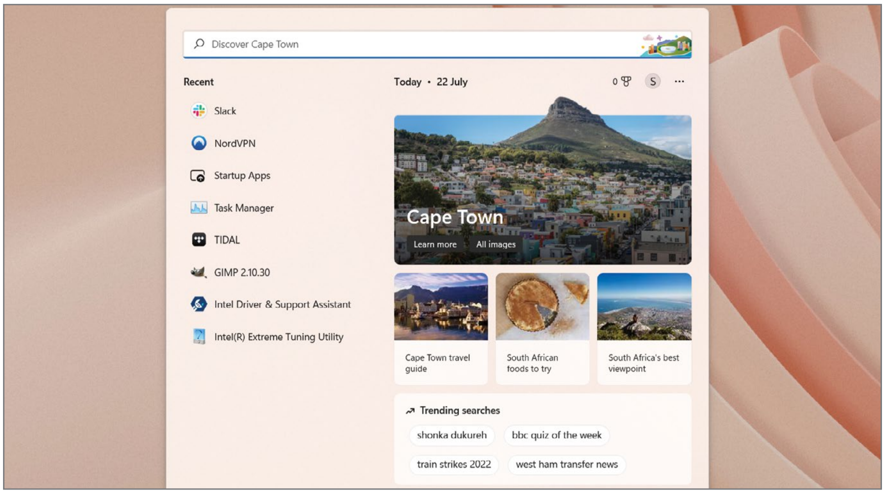
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH


Discover Cape Town
Recent
Slack
NordVPN
Startup Apps
Task Manager
TIDAL
GIMP 2.10.30
Intel Driver & Support Assistant
Intel(R) Extreme Tuning Utility
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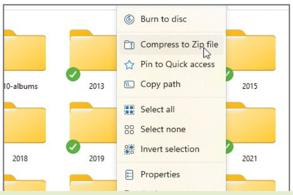
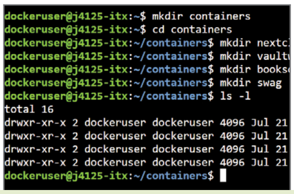
HANDY SHORTCUTS

Navigating around your PC using your mouse can be a little cumbersome, especially if you don't have an excessive amount of desktop space—plus it's so last millennium. To make life a little easier for yourself, you can use these nifty shortcuts to navigate around your PC faster. Press the 'Windows key + S' to quickly jump into your PC's search bar. To pop open file explorer, press the 'Windows key + E'.

MAKE – USE – CREATE


Burn to disc
Compress to Zip file
Pin to Quick access
Copy path
Select all
Select none
Invert selection
Properties
0-albums
2013
2015
2018
2019
2021

62
Reboot Windows 11 File Explorer with our tips and tricks.



```
dockeruser@j4125-itx:~$ mkdir containers
dockeruser@j4125-itx:~$ cd containers
dockeruser@j4125-itx:~/containers$ mkdir nextc
dockeruser@j4125-itx:~/containers$ mkdir vault
dockeruser@j4125-itx:~/containers$ mkdir books
dockeruser@j4125-itx:~/containers$ mkdir swag
dockeruser@j4125-itx:~/containers$ ls -l
total 16
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21
dockeruser@j4125-itx:~/containers$ █
```

66
Use Docker containers to run apps and services.

70
Our Machine of the Month, the TRS-80 from 1977.

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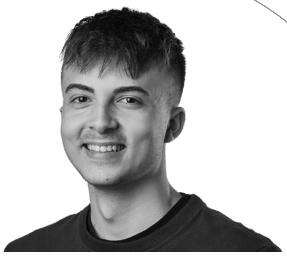


SAM LEWIS
STAFF WRITER

IN LIMBO MODE

In the previous issue, I mentioned that I should have been in a new property by now and well on the way to creating an awesome PC setup for both work and play. What has actually happened is that the move date has been shifted more times than the release of *Star Citizen*. This has been a major frustration as I'm itching to get my new long-term setup started.

On the other hand, I'm excited to tell you all that I'm now a fully-fledged member of *Maximum PC*! I had been freelancing for the past 18 months, but as a full-time member of the team, I am thrilled to see what the future holds. Hopefully, I'll make a better teammate at *Max PC* than I do with my mates on the new *Warzone* map, Fortune's Keep.

It's taken me a while to figure out how this new location plays and I'll be the first to admit that I've been letting the side down. I have been slowly improving but clearly hadn't played enough *Call of Duty* before the release of this update. I'm a fan of these 'smaller' maps—it's larger than rebirth island, small enough to have close-quarter gun fights, and big enough to make the most out of being a sniper. I tell everyone that the reason for my poor gaming ability is that I'm playing on a laptop. However, when I move, I'll have to think of another excuse.

↘ submit your How To project idea to: editor@maximumpc.com

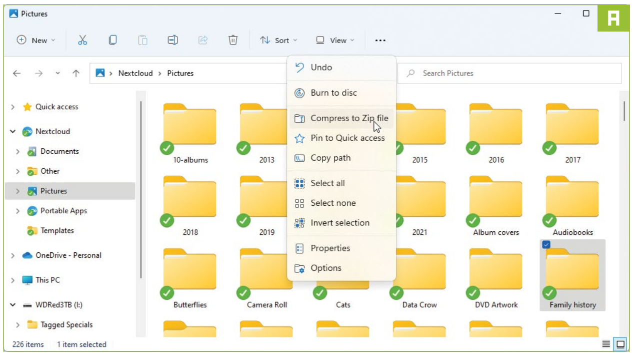
Reboot Windows 11 File Explorer

YOU'LL NEED THIS

WINDOWS 11 FILE EXPLORER plus some optional free apps to give you additional or improved functionality: WizFile, TeraCopy, ViVeTool, Win Subst, and TreeSize Free

THERE'S NO GETTING AWAY FROM IT: a core part of Windows 11 is File Explorer, the tool used to navigate and manipulate the files and folders on your PC. But for all the time you're using it, are you maximizing your use of File Explorer? It has come on leaps and bounds in the last few iterations of Windows, and there may be some hidden features you aren't aware of that could revolutionize the way you interact with your PC's drives.

That's where this latest collection of tips and tricks comes in. We'll start by highlighting some of the lesser-known tools within File Explorer that can help make your life easier. We'll explore third-party tools to fill in some of the gaps or even improve areas of File Explorer further—such as through faster file transfers or by allowing you to map local folders to drive letters for quick and easy access. We'll also give you a sneak peek at what's coming in the next major update as tabs make their long-awaited appearance, and point you towards some alternatives to File Explorer if it fails to meet your file-management needs. **–NICK PEERS**


A
Pictures
New
Sort
View
...
Nextcloud > Pictures
Search Pictures
Undo
Burn to disc
Compress to Zip file
Pin to Quick access
Copy path
Select all
Select none
Invert selection
Properties
Options
Quick access
Nextcloud
Documents
Other
Pictures
Portable Apps
Templates
OneDrive - Personal
This PC
WDRed3TB (I:)
Tagged Specials
10-albums
2013
2015
2016
2017
2018
2019
2021
Album covers
Audiobooks
Butterflies
Camera Roll
Cats
Data Crow
DVD Artwork
Family history
226 items
1 item selected

1 A NEW STREAMLINED RIBBON

One of the most visible changes in Windows 11's File Explorer is the stripped-back ribbon. Gone are the tabs of options and tools, replaced by a single row of buttons comprising the most used options, from cutting, copying, and pasting to renaming, deleting, and sharing.

» You'll also see that the New, Sort, and View options remain, along with a More (...) button covering useful, but less frequently accessed tools, such as burning discs or mapping and adding network drives [**Image A**]. Note, the More option is context-sensitive, so its contents will change depending on what you currently have selected.

» Compared with the ribbon found in Windows 10's File Explorer, the new version looks rather barren and simplistic. However, all the main features are still here, it's just that some of them are less visible than before. For example, the options to show item checkboxes (to easily select multiple files within a single folder), hidden items, and file extensions are now found under 'View → Show'.

» Elsewhere, features removed from the ribbon remain accessible from other locations. For example, the 'Pin to Quick Access' button has gone but you can still drag your chosen folder into the Quick Access menu or right-click it and choose 'Pin to Quick Access' instead.

» Similarly, the 'Add Columns' option for choosing what file information to show in the Details view has vanished from the ribbon, but you can simply right-click any of the column headers to reveal the same pop-up menu.

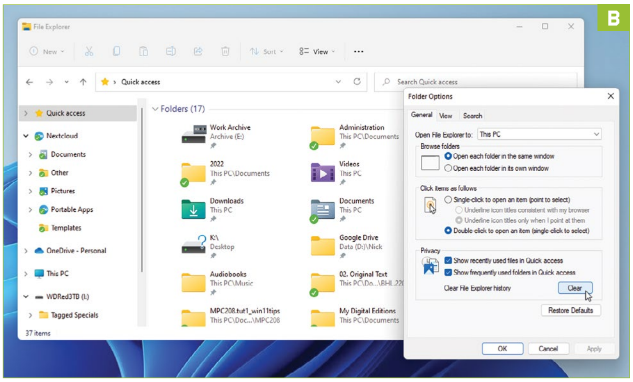
2 NAVIGATION PANE TIPS AND TRICKS

One of the biggest improvements to File Explorer came with the addition of the left-hand navigation pane in Windows 7. Here, you'll find all manner of shortcuts, and they're due to get a refresh in the next major Windows 11 update, due before the end of the year.

» A glance at the Insider Preview reveals that Quick Access has been replaced by a Home shortcut. To all intents and purposes, this is a slightly revamped version of Quick Access with a new, more logical name—see the annotation for details of what to expect. Thankfully, the tips you learn now will continue to apply to Windows 11 once Home makes its appearance.

» The navigation pane is home to various shortcuts—Quick Access/Home, This PC, Network, and selected cloud services you may have installed (including OneDrive). Click → to expand and navigate each in turn. They're largely self-explanatory, but the one that's of most use is Quick Access. Expand this to reveal its mix of any items you've manually pinned to it and frequently accessed folders. Click on Quick Access itself and you'll be whisked to its own folder where you'll also gain easy access to recently opened files.

» If you'd prefer to keep Quick Access for personal favorites only, click the More (...) button on the File Explorer command bar and choose Options, then untick either or both file and folder options under Privacy.


B
File Explorer
New
Sort
View
Quick access
Search Quick access
Folders (17)
Nextcloud
Documents
Other
Pictures
Portable Apps
Templates
OneDrive - Personal
This PC
WDRed3TB (I:)
Tagged Specials
37 items
Work Archive
Archive (E:)
Administration
This PC\Documents
2022
This PC\Documents
Videos
This PC
Downloads
This PC
Documents
This PC
K:\
Desktop
Google Drive
Data (D:)\Nick
Audiobooks
This PC\Music
02. Original Text
This PC\Do...\BHL.22
MPC208.tut1_win11tips
This PC\Doc...\MPC208
My Digital Editions
This PC\Documents
Folder Options
General
View
Search
Clear
Restore Defaults
OK
Cancel
Apply

Open File Explorer to: This PC

Browse folders
● Open each folder in the same window
○ Open each folder in its own window

Click items as follows
○ Single-click to open an item (point to select)
○ Underline icon titles consistent with my browser
● Underline icon titles only when I point at them
● Double-click to open an item (single-click to select)

Privacy
☑ Show recently used files in Quick access
☑ Show frequently used folders in Quick access
Clear File Explorer history

Alternatively, click Clear to remove the current list while keeping the option active in the future [**Image B**].

» While you're here, switch to the View tab and scroll down to the Navigation pane section where you can, if you wish, disable the Network and This PC view, plus choose to display libraries (depreciated, but clinging on). Choose 'Show all folders' and everything except Quick Access is collapsed into an all-encompassing 'Desktop' view, allowing you to technically access any folder or file from the navigation pane; it does, however, make for a messier view.

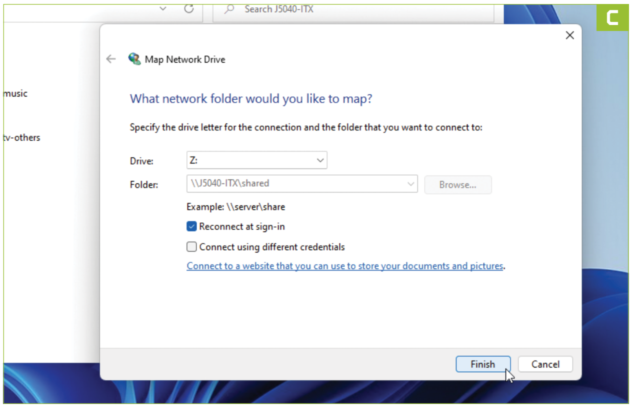
3 MAP NETWORK FOLDERS TO DRIVE LETTERS

One way to simplify access to network folders is by assigning them a drive letter—this is particularly handy when the network share doesn't appear as a shortcut under Network. The procedure for doing this hasn't changed—browse to the network folder in question or, if you don't have direct access, type its address into File Explorer's Address Bar like so:

```
\\DEVICE\pathto\folder
```

» You'll be prompted to supply network credentials if required—you'll need to tick the 'Remember my credentials' box for drive mapping to work. Before doing so, understand that saving your username and password opens the possibility of any ransomware infection on your PC spreading to encrypt files on the network share too.

» If you don't need read/write access to that share, we strongly recommend adding a user with read-only access to the shared folder and using that to log on; otherwise, make sure the server regularly backs up the shared folder to a secure location to provide you with some mitigation should the worst happen.



Map Network Drive

What network folder would you like to map?

Specify the drive letter for the connection and the folder that you want to connect to:

Drive: Z:

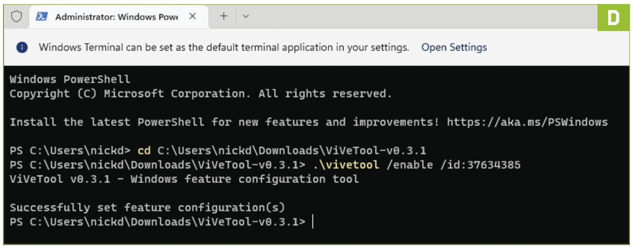
Folder: \\J5040-ITX\shared

Example: \\server\share

☑ Reconnect at sign-in

☐ Connect using different credentials

Connect to a website that you can use to store your documents and pictures.



Windows Terminal can be set as the default terminal application in your settings.

```
Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Install the latest PowerShell for new features and improvements! https://aka.ms/PSWindows

PS C:\Users\nickd> cd C:\Users\nickd\Downloads\ViVeTool-v0.3.1
PS C:\Users\nickd\Downloads\ViVeTool-v0.3.1> .\vivetool /enable /id:37634385
ViVeTool v0.3.1 - Windows feature configuration tool

Successfully set feature configuration(s)
PS C:\Users\nickd\Downloads\ViVeTool-v0.3.1> |
```

» After you're connected, select the folder you wish to map and press Shift + F10 to bypass the new context menu and go straight to the classic right-click menu from where you can select 'Map network drive…' Specify which drive letter you'd like to assign to the shared folder, leave 'Reconnect at sign-in' ticked and click Finish [**Image C**]. Now you'll be able to jump straight to that folder via This PC—you'll see the drive letter appear under Network drives. To remove the connection permanently, select the drive, press Shift + F10 again, but this time choose Disconnect.

4 FIND FILES ON YOUR PC

Once upon a time, Windows would take forever to search your hard drive for files. Then along came indexed searches with the promise that they would be much quicker. Indexed searches can also search file content as well as the filename for matches. Access is through File Explorer's search tool, located just below the main command bar.

» Navigate to the top level of your search (such as Documents or a specific drive), type your keyword(s) then hit Enter and the results will be displayed—depending on the speed of the drive and whether you've indexed the location or not, searches can take a few minutes to complete, although results will start to appear almost immediately.

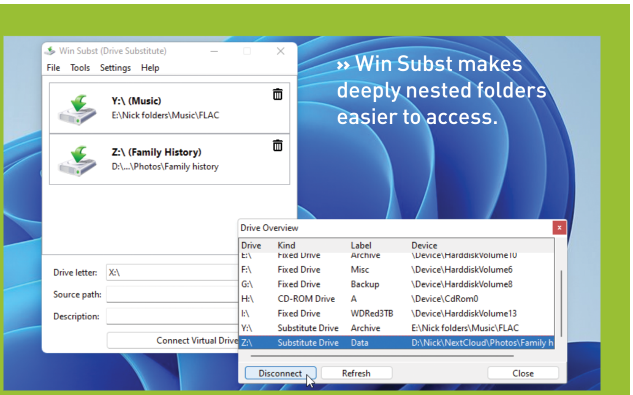
» If too many results are returned, you can refine your search from within the tool. Click the 'Search options'

MAP LOCAL FOLDERS

Mapping network folders to drive letters is a great way to simplify access to remote shares, but what about being able to map deeply buried folders on your local hard drive too? This functionality doesn't exist within Windows but can be added with a smart portable tool called Win Subst (www.no-nonsens.nl/win-subst/).

Once downloaded (note it's 64-bit only) launch Win Subst and click … next to Source path to define your first folder. Pick a drive letter, add a description, and click Connect Virtual Drive to create a link. One drawback is that it shares the same drive label as its parent drive in File Explorer.

By default, any mapped drives will vanish as soon as you close the program or reboot your PC. You'll find two options under Settings to change this: untick 'Disconnect on Exit' to keep them alive after closing the program, and tick 'Auto Start after logon' to bring them back automatically each time you restart Windows. To back up your folder configuration, choose 'Tools → Export Configuration' and save the .wsub file; the Import option for restoring them is also under Tools. For an overview of all drives, choose 'Tools → Drive Overview'.



Y:\ (Music)
E:\Nick folders\Music\FLAC

Z:\ (Family History)
D:\...\Photos\Family history

Drive letter: X:\

Source path:

Description:

Drive	Kind	Label	Device
E:\	Fixed Drive	Archive	\Device\HarddiskVolume10
F:\	Fixed Drive	Misc	\Device\HarddiskVolume6
G:\	Fixed Drive	Backup	\Device\HarddiskVolume8
H:\	CD-ROM Drive	A	\Device\CdRom0
I:\	Fixed Drive	WDRed3TB	\Device\HarddiskVolume13
Y:\	Substitute Drive	Archive	E:\Nick folders\Music\FLAC
Z:\	Substitute Drive	Data	D:\Nick\NextCloud\Photos\Family h

» Win Subst makes deeply nested folders easier to access.

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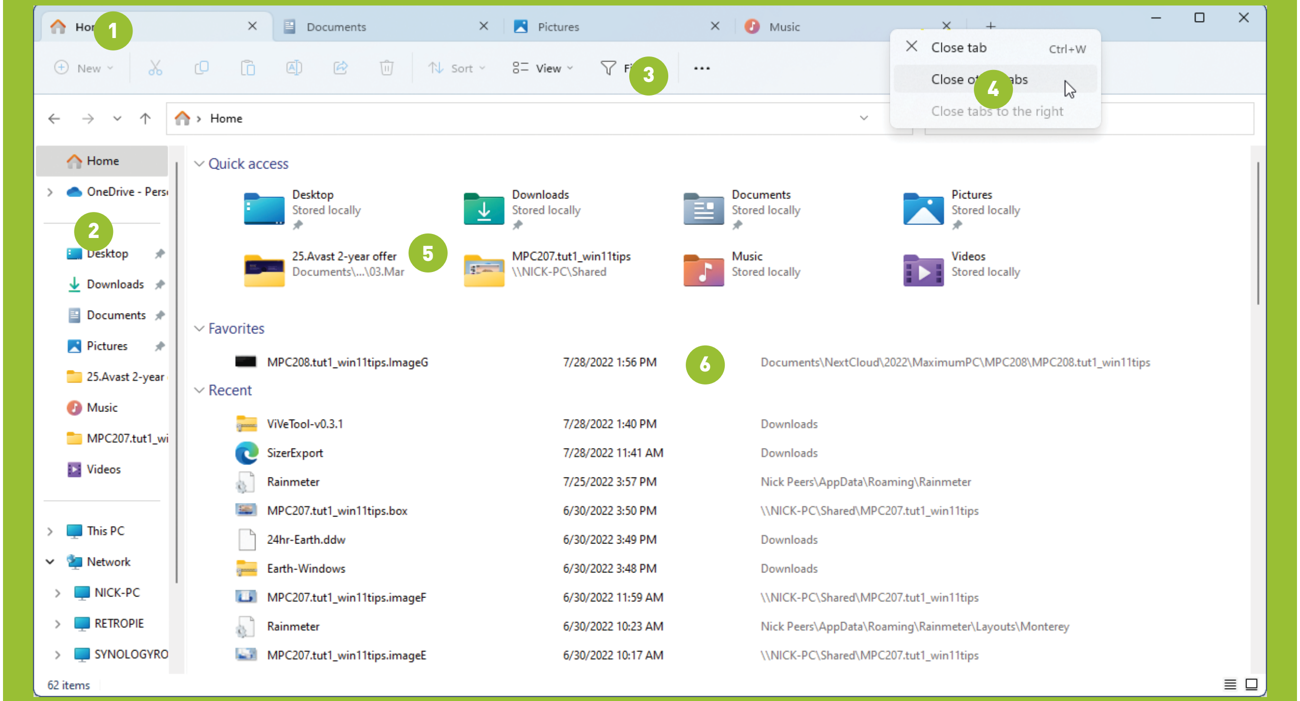
FILE EXPLORER UPGRADE


Home
1
Documents
Pictures
Music
Close tab Ctrl+W
Close other tabs
4
Close tabs to the right
New
Sort
View
Filter
3
Home
2
OneDrive - Personal
Desktop
Downloads
Documents
Pictures
25.Avast 2-year
Music
MPC207.tut1_wi
Videos
This PC
Network
NICK-PC
RETROPIE
SYNOLOGYRO
Quick access
Desktop
Stored locally
Downloads
Stored locally
Documents
Stored locally
Pictures
Stored locally
25.Avast 2-year offer
Documents\...\03.Mar
5
MPC207.tut1_win11tips
\\NICK-PC\Shared
Music
Stored locally
Videos
Stored locally
Favorites
6
Recent
62 items

MPC208.tut1_win11tips.ImageG	7/28/2022 1:56 PM	Documents\NextCloud\2022\MaximumPC\MPC208\MPC208.tut1_win11tips
ViVeTool-v0.3.1	7/28/2022 1:40 PM	Downloads
SizerExport	7/28/2022 11:41 AM	Downloads
Rainmeter	7/25/2022 3:57 PM	Nick Peers\AppData\Roaming\Rainmeter
MPC207.tut1_win11tips.box	6/30/2022 3:50 PM	\\NICK-PC\Shared\MPC207.tut1_win11tips
24hr-Earth.ddw	6/30/2022 3:49 PM	Downloads
Earth-Windows	6/30/2022 3:48 PM	Downloads
MPC207.tut1_win11tips.imageF	6/30/2022 11:59 AM	\\NICK-PC\Shared\MPC207.tut1_win11tips
Rainmeter	6/30/2022 10:23 AM	Nick Peers\AppData\Roaming\Rainmeter\Layouts\Monterey
MPC207.tut1_win11tips.imageE	6/30/2022 10:17 AM	\\NICK-PC\Shared\MPC207.tut1_win11tips

1. TABS
File Explorer's big new feature is tabbed browsing. Simply drag files and folders onto a tab to copy or move them to that location.

2. NAVIGATION PANE
The pane is now split into three sections and redesigned. Home is a new one-stop shop for favorite files and folders, including Quick Access, which now sits beneath it in the second section.

3. FILTER VIEW
When browsing the Recent list of files in the Home folder, you can now filter this view to show specific file types (Word, Excel, PowerPoint, images, videos, or PDF) using this button.

4. MANAGE TAB BAR
Tabs work in a similar way to the Edge browser—drag and drop to rearrange them, and right-click on the tab for further options.

5. HOME FOLDER
The Home folder is effectively a rebadged Quick Access folder. Click it and you gain access to both favorite and recently accessed folders and files.

6. FAVORITES
Users can now pin frequently accessed files to the Favorites section of Home. Note these won't show up in the navigation pane, so you'll need to visit the Home folder to access them.

menu to reveal options for filtering your search by various criteria: location (including whether to include subfolders), date modified, type, and so on. You'll also see a 'Change indexed locations' option—select this to choose which folders on your hard drive(s) should be indexed in addition to the defaults.

» You can also incorporate filters into your search terms—for example, typing maxpc kind:spreadsheets would only return spreadsheet files containing 'maxpc' in their filename. You can also search by specific file extensions using the 'type:' operator, such as type:docx or type:png.

5 SPEEDY FILE SEARCHES

There are several drawbacks with Windows Search: it's still not instantaneous, even with indexed drives. Windows 11 has dropped support for saving the results of frequently used search terms, forcing you to search from scratch each time.

» Thankfully, there's a much faster alternative for simple file or folder name searches: WizFile (https://antibody-software.com/wizfile/). WizFile is able to produce complete results within seconds on NTFS-formatted drives because it generates its own file index from the hidden Master File Table (other file systems are also supported, but not as quick to search). The best way to judge whether it works for you is to try it yourself.

» After installing (or choosing the portable version), launch WizFile and wait for it to quickly index your drive. Then type a keyword and watch in amazement as results appear in a flash.

» By default, WizFile searches for files and folders. Double-click a file to open it, or right-click for more options, such as opening the parent folder or copying the path to the clipboard. You can search for multiple keywords (just separate each keyword with a space) and perform 'OR' searches using the vertical pipe (|) operator, for example, 'maximum|minimum'.

» You'll also see three filters: click 'all types' to search for specific types of files, such as documents or pictures (select 'Options → Filters' to see what file extensions are included for each type of search, plus edit existing filters as well as create your own from scratch). Other filters let you apply file sizes and dates too.

» If you'd like to make WizFile more accessible from File Explorer, choose 'Options → Windows Explorer

Context Menu' to add WizFile to the classic menu that appears when you select a drive or folder and press Shift + F10.

6

FASTER FILE TRANSFERS

Don't get us wrong, File Explorer's ability to copy and move files has come on leaps and bounds in recent Windows iterations. We especially like the progress bar that allows you to keep an eye on file transfers, complete with pause and cancel options (pause comes in handy when you accidentally start two or three file transfers separately).

›› Even so, it's still not the quickest way to shunt files around your filesystem. You have a choice of two alternatives here: Teracopy (www.codesector.com/teracopy) and FastCopy (https://fastcopy.jp/). FastCopy is allegedly quicker, but Teracopy has the advantage of being able to integrate into File Explorer, so it can easily replace the native Windows file copying tool. Instead of choosing between them, why not try both? Install Teracopy for day-to-day transfers, then make use of FastCopy for occasional bulk transfers where its extra speed can make a difference.

›› Teracopy comes in free and Pro versions, but the Free version has all the functionality you need. Once installed, whenever you drag files from one File Explorer window to another, a pop-up menu will give you the choice of using Explorer or Teracopy—select the latter and you'll see the Teracopy window open with a progress bar and options for pausing, skipping, and stopping. If any file fails to copy due to corruption, Teracopy is smart enough to skip it and move on to the next.

›› You'll also see check boxes for unattended transfers, which prompt you to choose a default action on file conflicts, such as overwriting older versions automatically, and an option to verify the files after transfer.

›› By default, Teracopy only provides a progress bar for the current file being processed—click the left-hand button in the toolbar to reveal more information, including a left-hand pane providing details of the overall progress of your transfer in a similar vein to File Explorer. If you miss the File Explorer progress graph, you'll find this under Status.

›› We've barely scratched the surface of what Teracopy can do, but the key thing is that your files will transfer that bit quicker.

7

ADD TABS TO FILE EXPLORER

We've mentioned how the upcoming Windows 11 update should unveil a new version of File Explorer with support for tabs, but there's no guarantee that feature will roll out on your PC when the update ships. During the beta program, many users noted how File Explorer implemented some changes (specifically the new Home folder), but not others.

›› Luckily, you can enable the feature with the help of a third-party tool. Go to https://github.com/thebookisclosed/ViVe/releases and download the zip file for the latest version of ViVeTool. Once done, extract its contents, then copy the folder path (such as 'C:\Users\yourname\Downloads\ViVeTool v0.3.1') to the clipboard.

›› Now right-click the Start button and choose Terminal (Admin). Type cd and right-click to paste the folder path you just copied into the Terminal and hit Enter. Now type the following line:

```
.\vivetool /enable /id:37634385
```

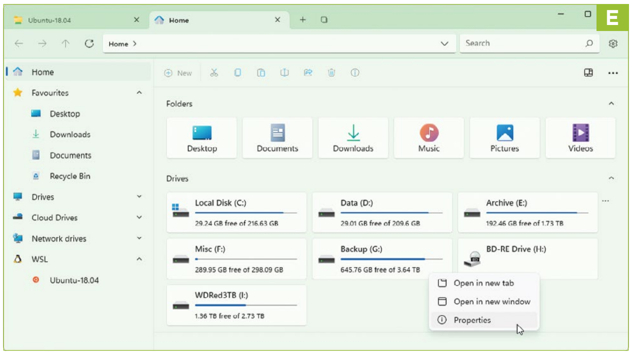
›› Hit Enter [**Image D**] and reboot your PC—tabs should now be present.

8

DITCH FILE EXPLORER

If File Explorer still doesn't float your boat, you'll find plenty of third-party replacements waiting in the wings to take its place. If you like the look of File Explorer, but only need a few additional extras, take a look at Files (https://files.community/). It looks almost identical to File Explorer but throws in tabs, color tags to label files and folders for easy identification and filtering, file previews, and a customizable color scheme for Files [**Image E**].

›› If you find yourself frequently returning to multiple sets of folders for different purposes, then Q-Dir (www.softwareok.com/?seite=Freeware/Q-Dir) may be a timesaver. It offers a four-paned window, each capable of supporting multiple tabs, so you can create different workspaces for different tasks. Overkill for most people, but it can be run as a portable app, allowing you to switch between it and File Explorer as you see fit. ⏻


E
Ubuntu-18.04
Home
Search
New
Home
Favourites
Desktop
Downloads
Documents
Recycle Bin
Drives
Cloud Drives
Network drives
WSL
Ubuntu-18.04
Folders
Desktop
Documents
Downloads
Music
Pictures
Videos
Drives
Local Disk (C:)
29.24 GB free of 216.63 GB
Data (D:)
29.01 GB free of 209.6 GB
Archive (E:)
192.46 GB free of 1.73 TB
Misc (F:)
289.95 GB free of 298.09 GB
Backup (G:)
645.76 GB free of 3.64 TB
BD-RE Drive (H:)
WDRed3TB (I:)
1.36 TB free of 2.73 TB
Open in new tab
Open in new window
Properties

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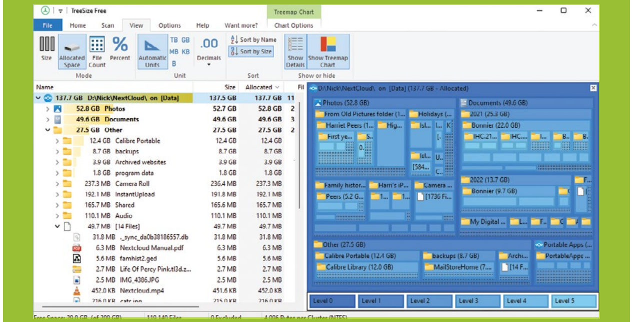
TRACK DRIVE SPACE


TreeSize Free
Treemap Chart
File
Home
Scan
View
Options
Help
Want more?
Chart Options
Size
Allocated Space
File Count
Percent
Automatic Units
Decimals
Sort by Name
Sort by Size
Show Details
Show Treemap Chart
Mode
Unit
Sort
Show or hide
Name
Size
Allocated
137.7 GB D:\Nick\NextCloud\ on [Data]
52.8 GB Photos
49.6 GB Documents
27.5 GB Other
12.4 GB Calibre Portable
8.7 GB backups
3.9 GB Archived websites
1.8 GB program data
237.3 MB Camera Roll
192.1 MB InstantUpload
165.7 MB Shared
110.1 MB Audio
49.7 MB [14 Files]
Photos (52.8 GB)
Documents (49.6 GB)
Other (27.5 GB)
Level 0
Level 1
Level 2
Level 3
Level 4
Level 5

While File Explorer's 'This PC' view can give you a basic overview of how much space each drive has free, it can't help you locate which specific files or folders are taking up the most space. You can do this manually, but there are lots of free tools out there that can do the hard work for you.

One such tool is TreeSize Free (www.jam-software.com/treesize_free), which quickly scans entire drives or selected directories to provide a visual map of what's taking up all that space. After launching, click the Select Directory button in the ribbon to select a drive or folder to scan. You'll be prompted to restart as an administrator, which is only required if the directory required contains restricted files (if you do so, TreeSize Free will pick up from where it left off—no need to select the folder a second time).

You'll be shown a two-paned window—a tree-like structure on the left and a chart on the right. The chart allows you to navigate between folders but won't show any files within those folders. Use the → button next to a folder in the navigation pane to view its contents.

Docker tips & tricks

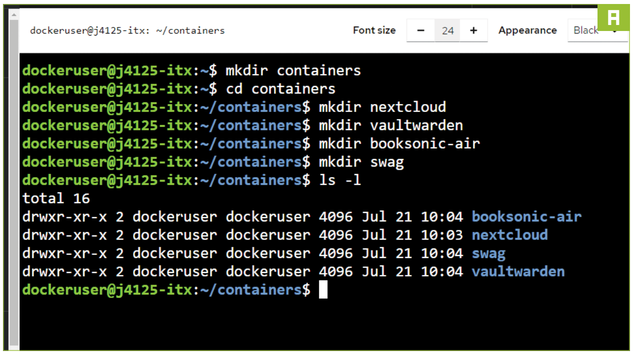
YOU'LL NEED THIS

DOCKER ENGINE, PLUS YOUR CHOICE OF CONTAINERS available for Linux, Windows, Mac, QNAP, and Synology

IF YOU FOLLOWED LAST ISSUE'S NAS SERVER BUILD, you'll have been left hanging with the tantalizing prospect of using Docker to run many, if not all, of your key services. Docker provides a clever way to run a wide range of applications and network services (from VPN and self-hosted cloud-style backup to media streaming) on any supported hardware.

Docker containers make it easy to run services in isolated bubbles, complete with their own dependencies and with tailored access to the outside world. At first glance, it can appear an impenetrable subject but in this tutorial, we'll show you how to install it on your system, set things up, get a firm understanding of the basics, and deploy your first containers, one to provide a convenient graphical front end, the other to set up a reverse proxy allowing you to securely access selected containers from outside your home network should you wish.

This tutorial focuses on those running a command-line version of Linux, such as Ubuntu Server as featured in last issue's NAS build. But you can easily run Docker natively on other platforms too—just skip the steps on configuring a dedicated Docker user account. **–NICK PEERS**



```
dockeruser@j4125-itx:~$ mkdir containers
dockeruser@j4125-itx:~$ cd containers
dockeruser@j4125-itx:~/containers$ mkdir nextcloud
dockeruser@j4125-itx:~/containers$ mkdir vaultwarden
dockeruser@j4125-itx:~/containers$ mkdir booksonic-air
dockeruser@j4125-itx:~/containers$ mkdir swag
dockeruser@j4125-itx:~/containers$ ls -l
total 16
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21 10:04 booksonic-air
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21 10:03 nextcloud
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21 10:04 swag
drwxr-xr-x 2 dockeruser dockeruser 4096 Jul 21 10:04 vaultwarden
dockeruser@j4125-itx:~/containers$ 
```

1 INSTALL DOCKER

Docker exists in many forms, such as Docker Desktop for Windows and Mac users, and Docker Engine for Linux command-line distros. Visit https://docs.docker.com/engine/install/ to click the relevant link for your operating system to access downloads and specific installation instructions.

» If you followed our advice from last issue's NAS build, your server will be running a version of Docker supplied by Ubuntu's own proprietary repository, snap. It works fine but isn't updated frequently. If you'd prefer to switch to Docker's repositories, simply follow the guide at https://docs.docker.com/engine/install/ubuntu/ but ignore the 'sudo apt-get remove' command listed, substituting it with this instead:

```
sudo snap remove docker
```

» Note, the installation process won't remove any existing containers, images, volumes, or networks you have installed.

» If you own a Synology or QNAP NAS, you can also install Docker on there—search for Docker (Synology) or Container Station (QNAP) in their respective app stores. Both provide their own user-friendly GUI interfaces for managing your containers, but you can also use our favored web-based front end, Portainer, if you wish.

2 CONFIGURE ROOTLESS ACCESS

Docker in Linux works by 'mapping' the container's internal user to your 'root' user, which isn't great for three reasons: security, the fact any files created by the container—such as configuration or data files—are owned by root (making them difficult to access), and the need to run Docker commands with the 'sudo' prefix.

» You can fix the last issue by adding your user name to the 'docker' group—any members of this group (created during Docker's installation) can launch Docker without sudo. To add your username:

```
sudo usermod -aG docker $USER
```

» If you want maximum security on your system, you might want to investigate Docker's rootless support (visit https://linuxhandbook.com/rootless-docker/ to find out more and follow a step-by-step install guide). However, it's not a perfect implementation.

» Thankfully, there's a halfway house between convenience and security. It requires you to source your containers from LinuxServer.io (www.linuxserver.io), where possible. LinuxServer.io has devised an elegant compromise, one that many other containers have applied too. Basically, all its container images allow you to supply a specific username's user (UID) and group (GID) ID during installation. The container then maps its internal user to the specified user as opposed to root.

» This has two advantages: the container's files are owned by that user instead of root, making them easier to access outside of Docker. The container's user also has more limited access to your system.

3 TIGHTEN SECURITY FURTHER

To maximize security, we recommend creating a dedicated non-administrative user for the task of running containers:

```
sudo adduser dockeruser
```

» This creates a dedicated user called 'dockeruser' (you're free to choose a different name, anything but 'docker'). Make a note of its group and user IDs (typically 1001) and supply a memorable password when prompted—how about docker for simplicity?

» Now log out of your own user account (cockpit users should click Session and select Log Out) and log into the dockeruser account you just created. From the Terminal screen, create the folder inside which you'll store all

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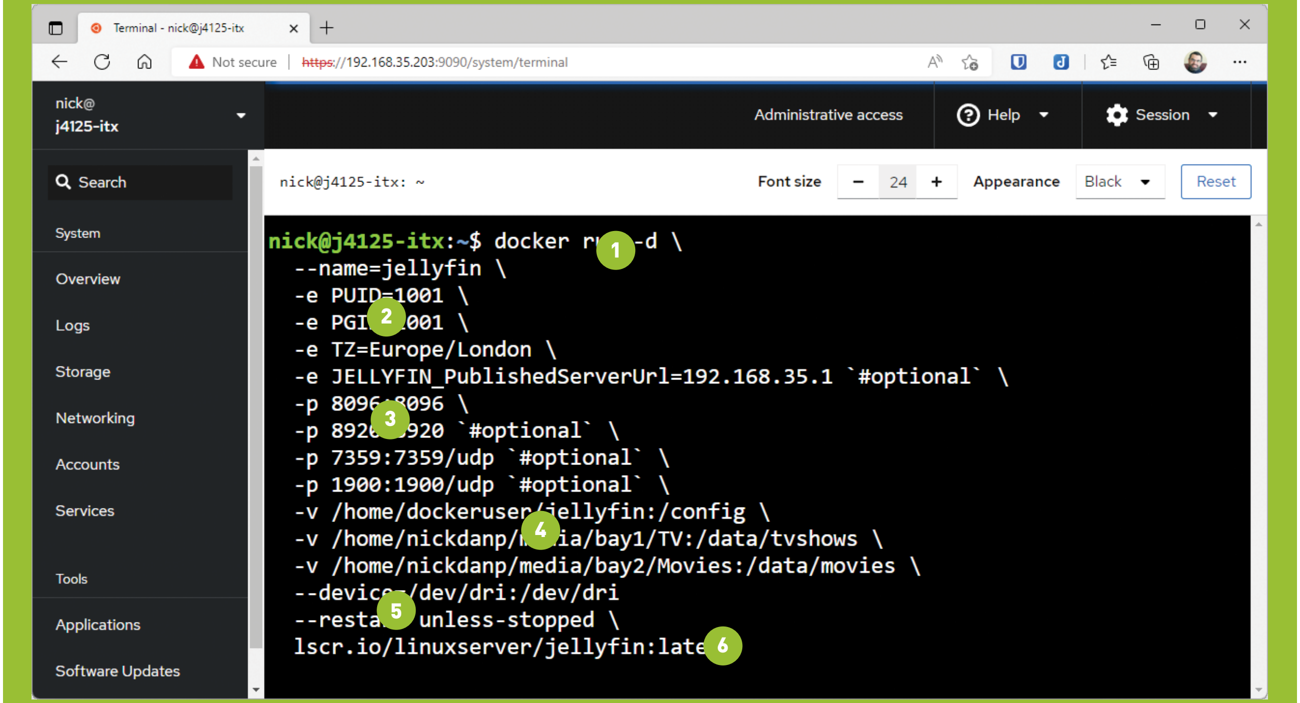
ANATOMY OF A CONTAINER



```
nick@j4125-itx:~$ docker r   -d \
  --name=jellyfin \
  -e PUID=1001 \
  -e PGI  001 \
  -e TZ=Europe/London \
  -e JELLYFIN_PublishedServerUrl=192.168.35.1 `#optional` \
  -p 8096 8096 \
  -p 892  920 `#optional` \
  -p 7359:7359/udp `#optional` \
  -p 1900:1900/udp `#optional` \
  -v /home/dockeruser/jellyfin:/config \
  -v /home/nickdanp/m  ia/bay1/TV:/data/tvshows \
  -v /home/nickdanp/media/bay2/Movies:/data/movies \
  --device=/dev/dri:/dev/dri
  --resta  unless-stopped \
  lscr.io/linuxserver/jellyfin:late
```

1. RUN INFORMATION
The '-d' tag instructs Docker to run the container 'detached', so it doesn't tie up the Terminal. The '--name' tag can be anything you like—it merely helps you identify the container.

2. ENVIRONMENT VARIABLES
The '-e' tags allow you to specify settings tailored to the container you're running. All Linuxserver.io containers include PID and GID variables for running containers more securely.

3. PORT MAPPING
The '-p' tags tell you which ports the container is listening on. If there's a potential clash with other services, choose a different port to listen on—eg. '-p 8080:80' redirects port 8080 to port 80 inside the container.

4. VOLUME MOUNTS
Allows you to map folders on your hard drive to the container, ensuring you can preserve configuration and data files when the container is restarted.

5. ADDITIONAL OPTIONS
The '-- restart' flag instructs the container as to how it should act when either the container or Docker itself are restarted.

6. CONTAINER IMAGE
The final line in any docker run command lists both the image and the version you wish to use to create the container. If necessary, this will be pulled (downloaded) to your hard drive first.

your container configuration files:

```
mkdir containers
```

» Each time you wish to set up a new container, you'll need to navigate inside containers and create your chosen container—for example:

```
cd containers && mkdir nextcloud
```

» If you know what containers you plan to set up, save yourself a bit of time and create all those container folders now [Image A]. Now log out and log back into your main user account and try to access the containers folder:

```
cd /home/dockeruser/containers
```

» You'll see a 'permission denied' message, confirming you're currently only able to access those folders (and their contents) when logged in as that user. To give your user read-only access to those folders:

```
sudo usermod -aG dockeruser $USER
```

» You need to log out (Session → Log out) and log back in for the change to take effect. To gain access to the folder via your membership of the dockeruser group, use the 'chmod' command:

```
sudo chmod -R 770 /home/dockeruser/containers
```

4 CREATING CONTAINERS

Containers are launched using 'docker run' commands. To see what makes up a typical Docker container, check out the annotation opposite, which shows what's needed to install the brilliant Jellyfin media server on your Intel-powered NAS, complete with support for hardware acceleration courtesy of the '--device' flag.

» A complete list of LinuxServer.io's containers can be found at https://docs.linuxserver.io/ in the menu under Images. Click each one to view detailed information on what it does, how it works, and the CLI script you need to follow to set up and launch the container.

» Because that CLI script will need tailoring according to the instructions provided, we recommend pasting it into a text editor first, then saving it as a text file. Editing this is far easier than trying to manually make changes in the Terminal, plus you'll have a copy of your perfect setup should you need to recreate the container in the future (say after updating the base image).

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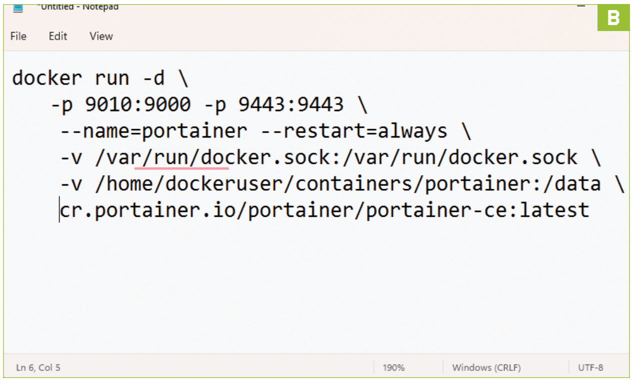
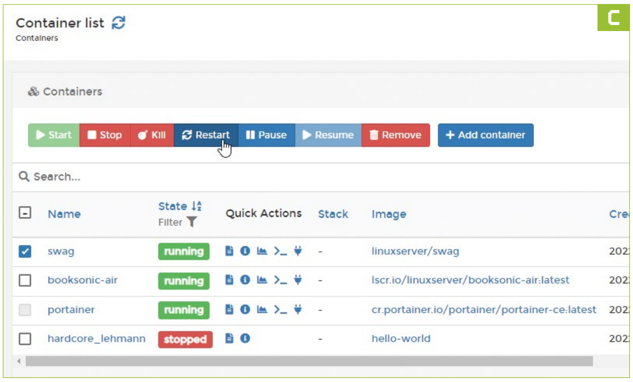


```
docker run -d \
    -p 9010:9000 -p 9443:9443 \
     --name=portainer --restart=always \
     -v /var/run/docker.sock:/var/run/docker.sock \
     -v /home/dockeruser/containers/portainer:/data \
     cr.portainer.io/portainer/portainer-ce:latest
```



☐	Name	State Filter	Quick Actions	Stack	Image	Cre
☑	swag	running		-	linuxserver/swag	202
☐	booksonic-air	running		-	lscr.io/linuxserver/booksonic-air:latest	202
☐	portainer	running		-	cr.portainer.io/portainer/portainer-ce:latest	202
☐	hardcore_lehmann	stopped		-	hello-world	202

›› When you're ready, either manually type the contents of the CLI script (press Enter after each \ character) into your Terminal or, if you're using cockpit, simply copy the contents to the clipboard, switch to cockpit's Terminal in your browser and press Shift + Insert followed by Enter.

›› One of the beauties of Docker is that if you make a mistake with your configuration and it either doesn't work as expected or fails to work at all, you've done no damage. Simply correct the CLI script and try again to recreate the container (use `docker rm --force containername` to remove the container if necessary).

5 ADD A WEB FRONTEND

There's no need to persevere with the command line when it comes to working with existing containers, whether it's viewing their status, removing them, or recreating them using the latest available image. While different graphical frontends exist, from Docker Desktop to the apps supplied for QNAP and Synology NASes, our favorite by far is Portainer (www.portainer.io). Deployed as a container, Portainer provides a consistent web-based frontend that you can access from any web browser on your network, making it perfect for any headless server.

›› The screenshot [**Image B**] reveals the script you need to deploy it. Once the instance has been created, confirm it's running correctly (`docker ps`) and then open a new tab on your web browser. Type https://192.168.x.y:9443 (substitute 192.168.x.y with your server's IP address) into your browser and skip through the now-familiar security warning (it's the same when you accessed cockpit for the first time).

›› You'll be asked to set up your initial user—this is basically the user you'll need to log on to the web interface, so be sensible (we recommend changing the username from the default 'admin' for example). Once done, you'll find yourself at the Environment Wizard, just click Get Started to visit the main Portainer screen.

›› You'll see your local Docker instance, complete with a list of stacks, containers, volumes, and images. Click this followed by the Containers link to view and manage all currently installed containers [**Image C**].

6 NETWORKING IN DOCKER

By default, all new containers are connected to Docker's default 'bridge' network. This makes them accessible through your host PC's IP address and whatever ports you've configured (Portainer is the obvious example here). They can pull data from the internet and can even be made accessible over the net by exposing their ports through your router's port forwarding. More on that shortly.

›› What the containers can't do is communicate directly with each other—that's because the default bridge network keeps them isolated. Should you need them to communicate with each other, you'll need to create a second bridge network, then connect them to it.

›› Thanks to Portainer, this is relatively simple to do. First, select Networks in the left-hand pane to view existing networks (bridge, host, and none). If you click bridge, you'll access its details screen—scroll down to see which containers are currently attached to it.

›› Return to the main Networks page and click 'Add Network'. By default, a new bridge network is to be created—that's what we want, so simply give it a suitably descriptive name (we went with bridge-for-all-seasons), scroll down and click 'Create the network'.

›› Next, you need to transfer those containers you want to communicate with each other to this new network. Click Containers followed by a container to access its properties screen, scroll down to the bottom, and click 'Leave network' next to its current network. Then select your new network from 'Join a network' and click 'Join network' [**Image D**].

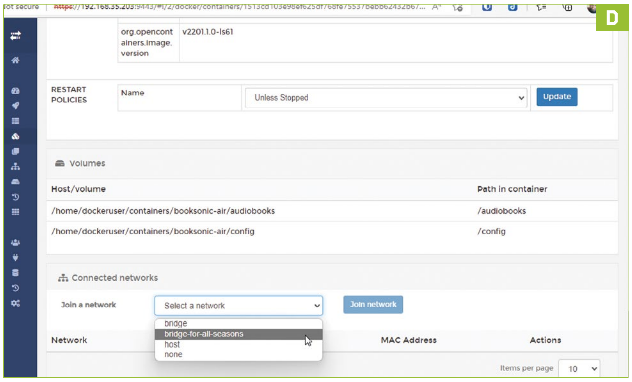
DOCKER 101

Docker runs your services within their own sandboxed environments called 'containers'. While it can help to think of them as virtual machines, there's no hardware or software emulation involved. They are sandboxed processes in memory running on your operating system. This means they're light on system resources, allowing you to run lots of containers at once, even on low-powered servers.

Containers are created from 'images' with everything needed to run that container—the software itself, plus any dependencies. These are housed in repositories such as the Docker Hub (https://hub.docker.com/) and are updated regularly, typically when the software is updated. Containers are non-persistent, which means when you shut one down and restart, it's effectively destroyed and recreated from scratch. Updating simply involves downloading the latest image and deploying it as your new container.

To avoid losing configuration settings and data, containers allow you to attach folders from your hard drive to the container. These 'volumes' are mounted to the container and contain persistent data that survives the container's destruction.

Containers can be joined to virtual 'networks' to allow them to communicate with your main PC and the outside world, whether other locally networked devices or over the internet. The default 'bridge' network allows you to communicate with your containers through a combination of your server's IP address and ports.



org.opencontainers.image.version	v2201.1.0-ls61

RESTART POLICIES — Name: Unless Stopped

Host/volume	Path in container
/home/dockeruser/containers/booksonic-air/audiobooks	/audiobooks
/home/dockeruser/containers/booksonic-air/config	/config

7 ADD A REVERSE PROXY (1)

If you have access to a domain name (or a free dynamic IP address from the likes of www.noip.com) and want to be able to securely access your containers from outside your network, then you'll need the help of two additional containers. These allow you to map your domain (or subdomains if you plan to connect through friendly addresses like nextcloud.yourdomain.com) to the relevant services on your network, which can be containers or services you've installed directly onto your server.

» Use your domain provider's tools to create your subdomains and point each of them to your current public IP address (as revealed by visiting www.whatsmyip.com). If your ISP provides you with a static IP address, skip to step 8.

» If not, you'll want to install the ddclient container that checks your public IP address every few minutes—when it detects a change, it informs your domain provider, which updates your domain to point to your new IP address.

» While you can create containers in Portainer, it's much quicker to do so from the command line. Go to https://docs.linuxserver.io/images/docker-ddclient to copy and paste the CLI script for ddclient into your text editor, then update the PUID and PGID environment variables, plus set TZ to your time zone. Point /config to the relevant folder on your hard drive, which you'll need to create while logged on as dockeruser, for example, mkdir /home/dockersetup/containers/ddclient and then paste the script into Terminal and hit Enter.

» Once ddclient is up and running, you'll need to navigate to /home/dockeruser/containers/ddclient and edit the ddclient.conf file (we recommend `nano ddclient.conf`). Scroll through the list until you find your domain or DDNS provider. Uncomment the lines and supply the information required. For example, Namecheap users must supply their domain name, their dynamic DNS password and the full subdomains, so nextcloud.domain.com or bitwarden.domain.com, and so on.

» After making your changes, switch back to Portainer, open the new ddclient instance and click Logs. This should hopefully confirm that ddclient is working as it should, but if you see any error messages, you'll need to troubleshoot. If you can't find a solution online, email The Doctor (doctor@maximumpc.com) to see if he can help.

8 ADD A REVERSE PROXY (2)

Now your subdomains know where to direct to, it's time to add the reverse proxy. We're using Linuxserver.io's swag, which will automatically obtain free LetsEncrypt SSL certificates for your subdomains (and renew them as and when required), plus handle the redirection of all services to their relevant containers.

» First, make sure any containers that will be exposed to the internet are on the same shared network bridge, then copy and paste the relevant CLI script from the swag web page (https://docs.linuxserver.io/images/docker-swag) into your text editor, and tweak accordingly. You'll also need to add the following line underneath '--name=swag':

```
--net=bridge-for-all-seasons \
```

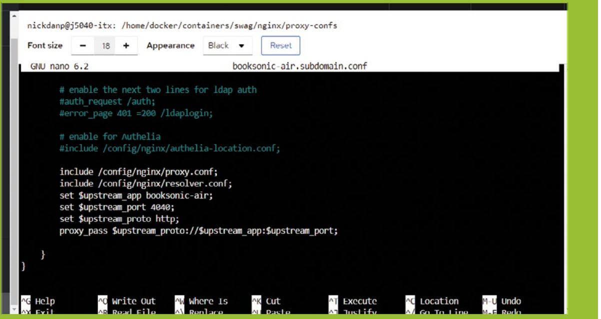
» You can add this line to any CLI scripts for containers you subsequently create to access through your reverse proxy.

» Once configured, paste into Terminal and launch – switch to Portainer and check the container's logs to see that the LetsEncrypt SSL certificates have been successfully generated. If they have, you're ready to configure the reverse proxy itself

» Start by logging into your router and checking the relevant ports for your containers (plus ports 80 and 443) are forwarded to your server's IP address.

» Once that's done, you'll need to edit some configuration files, one per container—see the box above for details.

REVERSE PROXY CONFIGURATION



```
nickdanp@j5040-itx: /home/docker/containers/swag/nginx/proxy-confs

GNU nano 6.2                    booksonic-air.subdomain.conf

        # enable the next two lines for ldap auth
        #auth_request /auth;
        #error_page 401 =200 /ldaplogin;

        # enable for Authelia
        #include /config/nginx/authelia-location.conf;

        include /config/nginx/proxy.conf;
        include /config/nginx/resolver.conf;
        set $upstream_app booksonic-air;
        set $upstream_port 4040;
        set $upstream_proto http;
        proxy_pass $upstream_proto://$upstream_app:$upstream_port;

    }
}

^G Help        ^O Write Out   ^W Where Is    ^K Cut         ^T Execute     ^C Location    M-U Undo
```

From the Terminal, browse to /home/dockeruser/containers/swag/ngnix/. Here, you'll find two folders: site-confs contains a single file called 'default' and proxy-confs contains a host of files covering most of LinuxServer.io's docker images. You can view these in your browser to get a feel for what's available and how they work at https://github.com/linuxserver/reverse-proxy-confs—there are both subfolder and subdomain conf files available, the latter is your focus if you're using subdomains.

Open one of the files in proxy-confs using nano, where you'll see several variables that may need amending to suit your specific container settings. For example, server_name points to your subdomain, while $upstream_app references the name of your container as defined by the --name tag when you set it up. If your container is supplied by Linuxserver, that should be all you need to configure. You'll find conf files for other services too—these may need more configuration, so be prepared to go hunting for extra help (email doctor@maximumpc.com if you hit a brick wall).

When you come to save the file, you need to remove the .sample extension from the filename (so nextcloud.subdomain.conf.sample becomes nextcloud.subdomain.conf) to make it 'live'. It should then come into effect—if you've configured it right, forwarded the correct ports from your router to your PC, and set up your subdomain, you will be able to access it via https://subdomain.domain.com in your browser.

© DOCKER.COM

Machine of the Month: Tandy TRS-80 (1977)

YOU'LL NEED THIS

A COPY OF TRS80GP
Windows, Linux, and Mac OS are supported System ROMs and boot software are supplied.
http://48k.ca/trs80gp.html

IN THE FINAL INSTALLMENT of this series, we are covering the third machine in the 'Holy Trinity' of microcomputers launched in 1977. Tandy/Radio Shack's TRS-80 was the plucky underdog of the trio but played a big part in helping to establish home computing. Pitched against rivals from Commodore and Apple, the TRS-80 was the cheapest option of the three, bringing computing to the masses long before Commodore would seize the lower market.

For those willing to dive in, the TRS-80 has a large gaming library with plenty of classic titles. However, emulating the platform can be tricky, so, after a brief history lesson on the machine, let us guide you through the process. –JOHN KNIGHT

1 DEVELOPMENT

Tandy's first foray into the computer market was based on the new Zilog Z80 processor, clocked at 1.78MHz. Early models shipped with 4KB of RAM. Graphically, the TRS-80 was monochrome, with a sophisticated 64-column text mode. However, to save a few dollars, standard units only shipped with uppercase letters, with lowercase support available with a ROM upgrade. The TRS-80's graphics mode is primitive and chunky, using a field of 128x48 'square dots'.

» Tandy's default monitor was a 12-inch black and white TV with minor modifications. The TRS-80 didn't have a speaker, but basic square wave tones could be sent through the cassette port.

» Three levels of BASIC were available: Level I, a simple 4KB variant; Level II, a 12KB Microsoft-licensed version with double-precision floating point operations; and Level III, a tape-based version of Extended BASIC with Tandy Enhancements.

» The TRS-80 was launched on 3rd August 1977, at $399 for the computer alone or $599 (around $2,680 today) for a base package, including a tape drive and monitor.

» Although the price was low, its options list was large and costly. Using a floppy drive required an expansion interface, and upgraded RAM or BASIC was expensive. An "Engineer" 16K package with Level II BASIC cost $1,457, and a "Deluxe Business" 32K cost an eye-watering $4,191.

2 SOFTWARE

Although the TRS-80 had business titles like Visicalc (1980) and Electric Pencil (1979), it was more popular in education and gaming. Gaming-wise, we were spoiled for choice with the TRS-80's extensive library. If you don't mind chunky monochrome graphics, you can expect surprisingly ambitious gaming, often fast-paced, with a crunchy soundtrack.

» For some personal favorites, *Crazy Painter* (1982) is a highly original concept with frantic arcade action; *Olympic Decathlon* (1980) is a keyboard-thrashing sports game from Microsoft with some beautiful animations; and for some cool voice synthesis, try frenzied space shooter *Defense Command* (1982).

» If you fancy some first-person/semi-3D action, some impressive titles are *13 Ghosts* (1982), a unique shooting gallery style game; tank shooter *Armored Patrol* (1981); "3D" space shooter *Stellar Escort* (1980); and *T80-FS1 Flight Simulator* (1980), which switches between cockpit view and bird's eye view.

» There are plenty of clone games, we liked *Galaxian* clone *Galaxy Invasion* (1980); *Penetrator* (1982), a *Scramble* clone that is probably better known than the original; *Defender* clone *Eliminator* (1981); and *Scarfman* (1981), a *Pacman* clone.

» A good software archive exists at www.classic-computers.org.nz, under DS System 80 --> Software, however, any TRS-80 fan should check out trs-80.com and cpmarchives.classiccmp.org/trs80.php.

3 RECEPTION AND LEGACY

Tandy planned to make a few thousand units—unsold stock could be used for Radio Shack inventory. However, demand was overwhelming, and by 1980, Tandy had sold three times as many units as Apple.

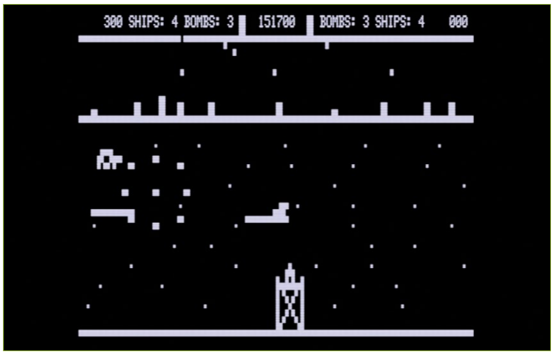
» In 1978, Tandy introduced a 5.25in floppy drive with an 85KB formatted capacity on single density disks.

» In October 1979, Tandy released a business-oriented follow-up, the Model II. This was incompatible with the original TRS-80, which was back-named the Model I.

» In July 1980, Tandy released the Model III, which was claimed to be 80 percent backward-compatible with the Model I. These included lowercase characters as standard, a better keyboard, faster processor, faster tape access, 48KB maximum RAM capacity, and 180KB double-density single-sided disk storage. The Model III was popular in schools where its all-in-one case used fewer cables and made it harder to steal components.

» In April 1983, Tandy released the TRS-80 Model 4. This was backward-compatible with the Model III and sported a faster 4 MHz Z80A CPU, 80 column text, 64KB of RAM (upgradeable to 128KB), and 640x240 graphics.

» The TRS-80 line spawned numerous clones, including EACA's Video Genie in Hong Kong, and the



» **TRS-80 games, such as *Eliminator*, really punch above their weight, with cool voice synthesis, attractive text, industrial sound, and frenetic gameplay.**

© WILLIAMS ELECTRONICS

›› Tandy's default monitor was a 12-inch black and white TV with modifications. Basic tones could be sent through the cassette port.

Dick Smith System 80 line in Australia. The TRS-80 name was applied to unrelated products, such as the Model 100 and Pocket Computer, as well as the Color Computer series. When Tandy discontinued the line in 1991, it had sold around 2.4 million units.

4 EMULATION

Many emulators are available, but TRS80gp comes with system ROMs and supports Windows, Linux, and Mac.

›› Head to the website and download the ZIP file—the link is at the top of the page. Extract the ZIP file—inside it are multiple folders for different platforms. Under the windows folder is a standalone executable file, trs80gp.exe. Double-click to run it.

›› Under the linux-32 and linux-64 folders are also standalone executables, titled trs80gp. Depending on your distro, you may be able to run these files simply by clicking on them. Otherwise, open a terminal within the folder and enter the command:

```
$ ./trs80gp
```

›› The application starts a Model III by default, booting up a TRSDOS prompt. You can explore different machines under File → Change Model. Most software is for the Model I and Model III.

5 LOADING SOFTWARE

Most software online comes as disk images, but tapes can be loaded by dragging and dropping the cassette file onto the emulator window. For loading disks, see if the game has an autoboot function. If not, you have to manually enter commands.

›› To load a bootable disk, start with Drive 0, by clicking Diskette → :0 ←← (name of disk) →→ → Replace. Select your disk image from the file browser and click Open. Now restart the emulated machine by clicking File → Reset Button, or pressing Alt + F5.

›› If your program hasn't loaded but you find yourself at a DOS prompt, some games need to be in Drive 0 but still loaded manually. At the prompt, type:

```
DIR
```

›› This will give you a file listing. Unlike modern computers, the TRS-80 uses a forward slash instead of a period for separating file names from extensions. The extensions to look out for are CMD and BAS: CMD files are binary programs, BAS files are BASIC programs.

›› To use Zork's disk as an example, it lists two files:

```
ZORK/DAT    ZORK/CMD
```

›› To run the CMD file, enter the file name by itself:

```
ZORK
```

›› Running BASIC programs is harder, as you have to invoke BASIC. To use Gammon as an example, which has the file name GAMMON/BAS, enter the following command, changing the file name between the quotes:

```
BASIC RUN "GAMMON/BAS"
```

6 IT STILL DOESN'T WORK!

If you received a "NO SYS" error or had a black screen, you will have to load things the hard way.

›› We recommend switching from TRSDOS, which is loaded by default, to LDOS which has much better compatibility. Note that system disks, like TRSDOS or LDOS, need to be in drive 0; whereas data disks, such as games, can be used in drives 1, 2, and 3.

›› Change the boot disk by clicking Diskette → 0: ←←TRSDOS13.dmk→→ → Eject. (Model I is labeled TRSDOS23.dmk). When you open the Diskette menu, the Drive 0 menu labeled "0:" will display as empty.

›› Open the Drive 0 menu and select LDOS. It can be difficult to spot, but for the Model I it will be called ld351-1.dsk and for the Model III it will be called ld3-531.dsk.

›› Now reset the emulated machine by clicking File → Reset Button, or pressing Alt + F5.

›› With LDOS now loaded, insert your program disk into Drive 1 by clicking Diskette → :1 ←empty→ → Insert disk, then choose your file. Browse Drive 1 by entering:

```
DIR :1
```

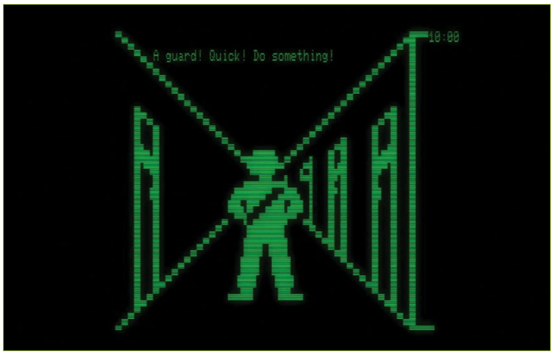
›› Now you can load files the same way as above with our Zork and Gammon examples—no drive numbers need to be entered, the TRS-80 will find the file regardless of which drive it's on.

›› Finally, if a game asks you to press the Clear button, this is mapped to Home on a modern keyboard.

SPECIFICATIONS

TRS-80 ORIGINAL SERIES (MODEL I): (1977)

CPU:	Zilog Z80 @ 1.78MHz
ROM:	12KB
RAM:	4-48KB
Graphics:	Monochrome text, 16 lines x 64 characters; 48 x 128 graphical 'square dots'
Storage:	Cassette, 5.25-inch floppy, hard disk
OS:	Microsoft BASIC (ROM), TRSDOS, LDOS, NewDos/80, CP/M
Released:	August 1977
Production:	1977-1981, 1991 (Model 4)



A guard! Quick! Do something!

›› Although there are plenty of standard text adventures, titles such as *Asylum* (1981) integrate early graphics and additional gameplay elements.

© WIKIPEDIA, MED SYSTEMS SOFTWARE

LAB NOTES

GUY COCKER, EDITOR-IN-CHIEF

Tomb Raider Live Experience

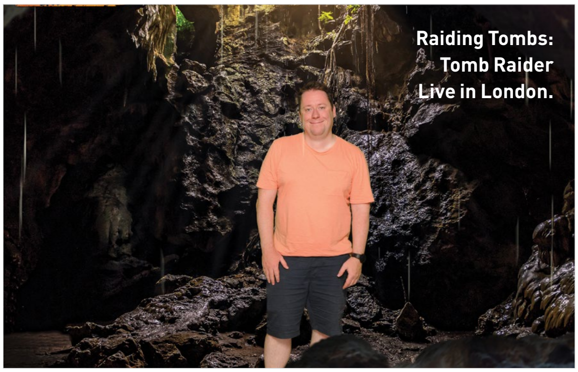
Becoming Lara Croft

THIS MONTH, I headed to London, England, donned my combat pants, and tried out the new *Tomb Raider* Live Experience. Based on the video game series, TRLE is a 90-minute adventure set in the *Tomb Raider* universe that's best imagined as a mix of escape rooms, immersive theater, and *Krypton Factor*-style physical trials.

It's a fun idea from a company that also recreates the *Crystal Maze* TV show, catering to corporate team-bonding days and bachelor/bachelorette parties. You are one of Lara Croft's team on an adventure, traveling the globe to solve puzzles, collect artifacts and discover treasure.

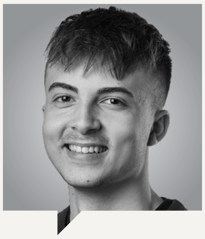
While you don't interact with Lara, Alicia Vikander from the 2018 *Tomb Raider* film does turn up in voice form, while you meet characters from the game, such as recent villain Aiden. It's hokey, with an am-dram feel to the acting, but if you can suspend disbelief during the short character interactions, the challenges, puzzles, and video game-like shooting sections are fun enough to get wrapped up in Lara's world.

I took part in a group of four, including a mother and her young daughter. The game would be easier with the maximum team size of eight because as anyone who's done an escape room will attest, it helps to have more hands when searching for hidden objects and brains solving different puzzles. The most pleasing part of the experience was seeing the young girl fearlessly throwing herself down death slides and into tight crawl spaces to collect artifacts, putting us adults to shame.



Raiding Tombs: Tomb Raider Live in London.

The TRLE is currently only available in the UK, although a Mario Kart-esque karting experience is also in the works. With the *Tomb Raider* game series being sold by Square Enix to Embracer Group and the movie rights expiring recently, who knows whether TRLE will make it over to the US. But if you're a fan of the games and are ever in London, I heartily recommend it.



SAM LEWIS

Staff Writer

I have dedicated what feels like a good chunk of my life trying to fix my BMW 3 series car. Now, this might sound as if I'm straying away from PCs, but conventional desktop computers and the ECUs of the car world have more in common than you might think. Getting from A to B in my car isn't simple, as I have to stare straight into the eyes of my check engine light—though, for the record, I do look at the road too. Although my car seems to be driving as it should, the light will not shift from the dash.

However, I have recently put what I've learned through my past 18 months of PC-building to good use. The basic principles are the same, it's a bundle of components thrown together to create something else. I guess that also applies to many other things, but you catch my drift.

There have been plenty of hiccups along my PC building path but when they arise, research and trial and error have gotten me through. It has certainly made me more hands-on and given me the confidence to take on some German engineering in my car. I cleared my check engine light, and most importantly saved a few dollars. I replaced my MAF sensor and air filter, cleaned the manifold, and replaced the EGR valve to resolve the issue. The moral of the story is: if you can build a PC, chances are you can apply these skills to other types of hands-on engineering.

HP's latest ultra-light Elite Dragonfly G2 laptop demonstrates x86's efficiency issues.

Editor's Pick: HP Elite Dragonfly G2

This x86 power problem really needs sorting

I AM A PRETTY heavy laptop user these days. I have a desktop test rig that doubles as an occasional gaming platform, but day-to-day, I use portables. I even use them for reviewing screens, as it makes the logistics and setup so much easier. I have a high-end laptop with a 3080 Ti GPU, so I can do a proper job of reviewing gaming panels up to and including 1440p models. 4K is theoretically doable, but I'm not convinced that mobile GPUs can crank out sufficient frame rates to do high-refresh 4K monitors justice. Anyway, the point is that I do most stuff with laptops, even performance-intensive work.

It says a lot about how far the PC platform, including x86 CPUs, has come. There's not much in it regarding CPU performance when it comes to desktop versus laptop. Desktop is clearly faster, but it's a percentage thing rather than being three or four times more powerful.

Yet x86 still has a long way to go when it comes to power efficiency. That performance laptop I use for reviewing screens? It gets hot and the fans spin up just sitting idle while I fiddle with display settings on the screen's OSD menu. That's a hefty machine with the fastest available components, but I've unboxed HP's latest ultra-light Dragonfly portable running a specialized low-power U-series CPU and that gets warm just sitting doing nothing.

I'm not sure I should admit this, but as a sideline, I review screens for Macs and I also run a MacBook Air with the M1 processor. To get that thing slightly warm, you have to be doing something full-on. You can have a zillion browser tabs open and the temps barely budge. On an x86 machine, the fans would be freaking out.

Moreover, the M1 Air doesn't have fans, as it genuinely doesn't need them. Once you've properly experienced a laptop with no fans that rarely gets hot, pretty much every laptop PC feels clunky and ancient. I've run a lot of high-performance laptops over the years and, without exception, they degrade over time, something I've mentioned previously in this column. Which you'd expect given the thermals are marginal when new and only get worse as dust builds up and the thermal paste ages.

The problem, then, is that it's not hard to see where more performance is coming from with x86 CPUs. Intel and AMD roadmaps are full of next-gen CPUs with more cores and more performance. But what about efficiency? That HP laptop runs Intel's latest efficiency cores in ultra-low voltage format and it still couldn't possibly be built without fans.

Sure, process technology will help. But Intel's latest 10nm CPUs are massive power guzzlers, worse than its 14nm chips. AMD's Ryzen processors are generally better. But not dramatically. AMD has nothing that comes close to an Apple M1 chip for efficiency. To a large extent, that's a consequence of the x86 instruction set itself. It was never designed for power efficiency and, to date, nobody has managed to truly mitigate for that fact.

It's why Intel's attempt to make x86 chips for smartphones failed. And it's going to become an ever greater limitation in future. Chips like the Apple M1 have proved that ARM can close the gap when it comes to outright performance. Those M1 cores have excellent performance and outstanding IPC. But neither Intel nor AMD have solved the power efficiency problem for x86. If they don't, I can't see a long-term future for x86. I really can't. **–JL**

$1,999 , www.hp.com

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Reviewed…

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76 Colorful GeForce GTX 1630
78 NZXT H7 Elite

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82 ASRock RX 6750 XT Phantom Gaming D
84 BenQ Mobiuz EX3210U

87 Nubia Redmagic 7S Pro
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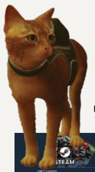
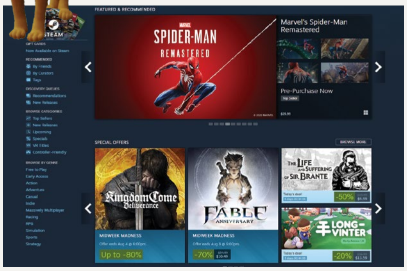
89 Corsair K70 Pro Mini Wireless



90 Stray



92 Steam vs. Epic Games Launcher

SK hynix
PLATINUM P41 NVMe

SK Hynix's M.2 drive has all the specs, including a multi-core controller and a PCIe Gen 4.0 interface.

SK Hynix Platinum P41 2TB

Welcome to the big league, SK Hynix...

SK HYNIX isn't one of the big boys when it comes to consumer SSD branding. But it is one of the heavyweights in NAND flash chips. In fact, SK Hynix is about to have even more weight to throw around thanks to buying Intel's SSD and flash memory business lock, stock, but minus the Optane barrel, the latter not available on account of being closed down entirely.

Anyway, the company's relative anonymity as a consumer SSD brand is about to change. The new SK Hynix Platinum P41 is a bit of a beast, a serious attempt at a high-performance M.2 drive. For starters, where the previous generation SK Hynix Gold P31 made do with a PCIe 3.0 interface and a controller chip with just four memory channels, the new P41 gets all the full specs.

SK Hynix says its new Aries controller chip serves up 33 percent faster I/O speeds and double the IOPS of the Cepheus controller. We also know it's a quad-core design with double the cores of the old Cepheus and ups the memory channel count to eight, which is more in line with the high-performance competition. For the record, SK Hynix allocates 1GB of its own in-house LPDDR4 cache memory per terabyte of flash storage. So, our 2TB review unit is rocking 2GB of cache.

As for the actual flash memory in the P41, it's SK Hynix's latest and greatest 176-layer 3D TLC, which is said to be around 40 percent faster than the previous 128-layer chips. All told, this 2TB drive is good for 7,000MB/s sequential read speed and 6,500MB/s writes. The 1TB model matches those speeds, but the 500GB/s version is a little slower for writes, clocking in at 4,700MB/s. However, claimed IOPS performance is the P41's real USP. SK Hynix reckons it's good for no fewer than 1.4 million read IOPS and 1.3 million write IOPS. Those figures bode well for 4K random access performance, which is arguably where the latest SSDs could do with a boost.

Rounding out the main speeds and feeds, SK Hynix rates this 2TB at 1,200TB for write endurance. Strictly speaking, that's well behind some of the competition. The Kingston Fury Renegade 2TB is rated at 2,000TB write endurance, while the Seagate FireCuda 530 2TB is up at 2,550TB. But it's still enough to write hundreds of GB a day for decades, so endurance isn't an issue.

But what about performance? When it comes to sequential throughput, the P41 is right up there with the best flash drives, whether that's the Samsung 980 Pro, the WD Black SN850, or the legion of drives powered by the popular Phison controller chip. In the end, they're all around 7GB/s and bumping up against the usable bandwidth of a quad-lane PCIe 4.0 interface. And while we're talking sequential throughput, we measured the P41's SLC cache at just over 300GB, which is similar to other 2TB TLC drives.

That's all good but we're disappointed by the P41's short queue depth 4K random access performance. It's comparable with the fastest drives, where we'd hoped it might just set a new standard. However, the P41 does beat all-comers and by some margin in the PCMark 10 overall storage benchmark score. What's more, it achieves lower latency than any other flash in PC Mark's latency test.

If we do have a reservation, it involves operating temps—71°C is pretty toasty. We didn't observe any throttling even after writing over 1.5TB of data. But this drive runs hot enough for us to worry whether throttling might be an issue in a few edge cases. That reservation aside, this is one heck of an SSD. –**JEREMY LAIRD**

VERDICT

9

SK Hynix Platinum P41 2TB

+ HEAVENLY CREATURE Great specs; strong performance; attractive pricing.

− FOUL BEAST Runs a little hot; not quite the game changer we'd hoped for.

$259, www.skhynix .com

BENCHMARKS

	Kingston Fury Renegade 2TB	**Seagate Firecuda 530 2TB**	**XPG Gammix S70 2TBFury Renegade 2TB**	**SK Hynix Platinum P41 2TBFury Renegade 2TB**
Peak Sequential Read (MB/s)	6,860	6,940	**6,950**	6,890
Peak Sequential Write (MB/s)	**6,440**	6,410	6,340	6,340
PCMark10 Storage Index (full)	3,177	3,021	2,879	**3,477**
PCMark10 Storage Bandwidth (MB/s)	510	487	458	**542**
PCMark10 Storage (full)	53	56	**58**	47
Peak Temperature (°C)	44	**41**	67	71
CrystalDiskMark 7.0.0 SEQ1M Q8T1 Read (MB/s)	7,344	7,334	**7,451**	7,375
CrystalDiskMark 7.0.0 SEQ1M Q8T1 Write (MB/s)	**6,897**	6,874	6,793	6,872
CrystalDiskMark 7.0.0 RND4k Q1T1 Read (MB/s)	**83**	**83**	74	**83**
CrystalDiskMark 7.0.0 RND4K Q1T1 Write (MB/s)	247	251	**262**	255

Best scores are in bold. Our test bench consists of an AMD Ryzen 7 3800X, ASRock Taichi B550, Nvidia GTX 1080, 16GB GSkill DDR4, and Sabrent Rocket 4 Plus OS SSD

SPECIFICATIONS

Format	M.2
Capacity	2TB
Interface	PCIe 4.0
Controller	SK Hynix Aries
Memory type	176-layer TLC NAND
Cache memory	2GB DDR4
Sequential read	7,000GB/s
Sequential write	6,500GB/s
Read IOPS	1.4M
Write IOPS	1.3M
Write endurance	1,200TB
Warranty	5 years

Colorful GeForce GTX 1630

Party like it's 2019 with this blast from the past

LAST MONTH, we looked at the rather disappointing Radeon RX 6400. This month, Nvidia's GTX 1630 gives us one reason to reconsider AMD's budget offering. Based on the four-year-old Turing architecture, but without ray-tracing hardware, the GTX 1630 feels like a GPU that's horribly late to the party. It might have made sense if it had launched alongside the GTX 1650 back in 2019, at a price south of $100. But today, with cards selling for $199? It's everything bad from 2021's GPU shortages, at a time when no one is interested in paying that much money for an underperforming card.

And underperform it does. Compared with the RX 6400, the GTX 1630 ends up being 36 percent slower at our mostly playable 1080p medium settings. It's also 32 percent slower at 1080p ultra, but when a card is failing to break 30fps, there's not much point in looking closer. At least seven of our eight test games broke 30fps at medium settings, but that still doesn't make up for the abysmal performance.

Not that we expected anything better. Nvidia took the same TU117 GPU that's used in the GTX 1650 (and MX450/MX550 laptop parts), disabled half the GPU cores and half the memory interface, and the resulting graphics card is about 40 percent slower than the existing GTX 1650 GDDR6. That's a slightly faster variant of the original GDDR5 card, with basically the same launch price of $149. Why does the GTX 1630 cost $50 more? Because it's 2022 and Nvidia apparently doesn't want to make any more GTX 1650 Super cards, or something.

Considering it has the aging Turing architecture, not to mention the trimmed features, such as the Pascal NVENC instead of the TU116's Turing NVENC, there's not much going on here to warrant a recommendation. At least AMD's card can be found in half-height slim designs with no power connector required.

Colorful still equips its card with a 6-pin power connector and a full height, dual-slot design. Maybe that's fine if you have a larger PC but, in that case, we can readily point to several dozen different GPUs that are a better choice than the GTX 1630—the old GTX 970 from 2014, for example, can be found for under $100 on eBay, and it's 40–50 percent faster than this slothful GPU.

So, who is this card for? It's a desktop version of the mobile MX450, which was nothing to write home about. No one invited the MX450 to gaming parties, and even if it did try to drop in uninvited, it would be likely to end up in the bathroom all night. If this were a sub-$100 card, we could at least find some redeeming qualities. It's faster than the GTX 1050 at least, barely, and by extension that makes it a much better choice than the GT 1030 GPUs that were one of the few options in stock last year. But it's no longer 2021 and the GPU shortages are thankfully disappearing in the rearview mirror. At the current going rate, we simply can't find any good reason to recommend the GTX 1630.

If you want a modest GPU that still has hardware video encoding support—one of the features AMD's RX 6400 lacks—you can find a used GTX 1650 Super for less money. It will use a few more watts of power, but that hardly matters, especially considering you get better encoding hardware and double the performance. Even if the pricing gets adjusted to something more sensible, that same recommendation would still apply: the GTX 1650 Super is twice as fast and universally superior hardware.

We were hoping to have Intel's Arc A380 in for review as a potential alternative to the GTX 1630, but that didn't happen. Word is that Intel's drivers are broken even now, several months after the China launch. We'll look at that GPU next month and, in some ways, it might even fall behind the GTX 1630. But outside of people like us that play GPU Pokémon—gotta catch them all!—you should steer clear of Nvidia's lowest spec GTX 16-series part. –**JARRED WALTON**

BENCHMARKS

	GTX 1630	RX 6400	GTX 1650
Eight-game average	37 / 18	**56** / 26	55 / **29**
Borderlands 3	35 / 17	**62 / 31**	57 / 29
Far Cry 6	39 / 24	**62** / 29	**62 / 43**
Flight Simulator	28 / 16	42 / 25	**45 / 28**
Forza Horizon 5	41 / 16	**66** / 22	64 / **27**
Horizon Zero Dawn	37 / 27	**62 / 43**	56 / 40
Red Dead Redemption II	53 / 18	**70** / 26	61 / **30**
Total War: Warhammer III	21 / 11	26 / 12	**33 / 18**
Watch Dogs Legion	37 / 15	**62 / 22**	59 / 20

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average framerates at 1920x1080 medium/ultra.

VERDICT

4

Colorful GeForce GTX 1630

+ **FASHIONABLY LATE** Faster than GTX 1050; has hardware encoding; full x16 PCIe interface.

− **NOT INVITED** Overpriced; slower than most GPUs; old technology.

$199, en.colorful.cn

SPECIFICATIONS

Architecture	TU117
Lithography	TSMC 12FFN
Boost Clock	1785MHz
GPU Cores	512
Memory	4GB 12Gbps
TFLOPS FP32	1.8
Bandwidth	96GBps
TBP	75W
Connectors	HDMI 2.0, DisplayPort 1.4, DL-DVI-D

The TU117 GPU at the heart of the GTX 1630 came out three years ago, and the passing of time hasn't done it any favors.

NZXT H7 Elite

The best of the best from NZXT?

THE H7 SERIES is a newly revised lineup of mid-tower cases from NZXT, with the H7 Elite at the top of the tree. Below it sits the H7 flow and the standard H7, both coming in at just below $130. It's no great shock that NZXT knows how to make a good-looking PC chassis, and these three cases don't buck the trend. NZXT claims the series has been created with the aim of being easy to build in, with plenty of interior space and versatility. However, the H7 Elite model we have on test is the one with all the bells and whistles. So, is it worth splashing out an extra $70 for the Elite over the Flow, or indeed the Standard version?

All three cases have a similar design, but the H7 Elite is the cleanest with a front tempered glass panel that shows off the three pre-installed 140mm F series RGB fans. Our matte black offering benefits from having the glass panel at the front as the RGB light bounces off the glass from all angles. If you fill your case with the same fans, this should provide you with an even flow of color throughout. However, the glass front panel is more for show. If you're after the best PC performance, opting for the perforated front panel from the Flow option would make more sense.

Opening this case requires no tools, which is always a bonus. The panels easily pop off with a pull and lift motion, making it a breeze to get in and out of. Take care though, as you now have to worry about breaking two glass panels with the H7, rather than one. If the worst did happen though, you'd at least have better airflow. Talking of which, there is a side vent on the back to allow air into the case as air cannot travel through the glass.

This side air duct is rather slim and further reinforces the idea that this case is more aimed at the PC builder who wants a showpiece case rather than a performance monster. It's a shame that there isn't another duct on the front to allow more air in though.

Around the back of the case, there are plenty of routes for cable management. In a mid-tower case such as this, it's essential to have various channels that your cables can follow. Especially if you have three case fans along the front and top, and one on the back, it can quickly get messy in the interior.

There are hooks and straps located all over the interior of the case so that you can easily tuck your cables away. Black cases always have an advantage in being able to better hide cables compared with the white versions, but still, there's no excuse for loose cables in the H7 Elite. Cable management aside, you'll also find the RGB and fan controller pre-built onto the back panel. The RGB here is only accessible via NZXT's CAM software, so bear that in mind when you're building.

Internally, the case has enough room for most build scenarios. Regarding fan support, you can fit either three 120mm fans or three 140mm fans at the front. On the top, you can fit three 120mm fans or two 140mm fans and, at the back, you can fit either one 120mm or 140mm fan, which should be enough. Radiator support is equally impressive, offering space for a 360mm radiator at both the front and top and a 140mm radiator at the rear if required. In this case, the CPU cooler clearance is up to 185mm and for the GPU, there's 400mm of room.

Space is certainly a strong point for the H7 Elite, and so is the ease of access and use. NZXT has remained true to its word with this new H7 series, but we go back to our earlier point. Is the Elite version worth $70 over the flow? Though we love how the Elite looks, it is essentially the same case as the Flow, only with less airflow. Sure, you get the RGB fans with the Elite but the Flow is the best value for money in this range—we'd recommend staying clear of the Standard version as it costs the same as the Flow. The Elite is a great case, but it opts to go down the route of looks over performance. **–SAM LEWIS**

VERDICT
8

NZXT H7 Elite

+ TOP TIER VISUALS Great fan, radiator and storage support; charming style.

− FORM OVER FUNCTION Restricted airflow; cheaper Flow alternative is better value for money.

$200, www.nzxt.com

SPECIFICATIONS

Design style	Mid-tower
Motherboard support	Mini-ITX, Micro-ATX, ATX, and EATX (Up to 272mm)
Colors	Matte Black, Matte White
Window available	2x Tempered glass
Front I/O ports	USB 3.2 Gen 1 Type-A x2, USB 3.2 Gen 2 Type-C x1, 3.5mm headset audio jack
Radiator support	Front: up to 360mm, Top: up to 360mm, Rear: up to 140mm
Fan support	Front: 3x 120mm/ 3x 140mm, Top: 3x 120mm/ 2x 140mm, Rear 120mm/ 140mm
Graphic card clearance	400mm
Dimensions	19.8 x 18.9 x 9 inches
Weight	25.04lbs

NZXT's H7 Elite case looks great but the lack of airflow may be an issue.

Framework's laptop can be completely upgraded and repaired.

Framework Laptop

Do-It-Yourself Upgradeable Laptop

THE MOVE AWAY from easy-to-upgrade gadgets to devices that are impenetrable has to be one of the worst tech trends over the last 15 years. It's one of the reasons we've paused our repair guides in partnership with iFixIt—your laptop and phone have become unfixable to the average user. Sure, you can upgrade the RAM and SSD on most consumer laptops, and the Wi-Fi card if you're feeling adventurous, but if you want to upgrade anything else, you're basically looking at buying a whole new machine.

California-based Framework, founded just under three years ago, is attempting to do something about this problem and the e-waste it creates. Its Laptop is highly upgradeable, from an entirely replaceable mainboard inside, to the I/O ports on the outside, meaning you can in theory buy the laptop chassis once and then replace the bits that become outdated over time. It's a smart idea, both from the ease that it offers consumers the chance to upgrade, to the fact that it reduces the amount of waste each time.

That's the theory, anyway. Sadly, in reality, upgrading one of Framework's laptops is pretty expensive, to the point where many people would still be better buying a new laptop and 'recycling' the old one by selling it. Take our review model, for example—it originally housed an 11th Gen Intel Core processor and retailed for $899. We then upgraded the motherboard to the high-end 12th Gen Intel Core i7 1280P version, which costs $1,049 to buy on its own—almost as expensive as a new laptop. True, there are lots of DIY projects on Framework's website that repurpose your old motherboard and components, but many of them could also be achieved with a cheap Raspberry Pi or similar micro-computer.

A FUN WEEKEND

The upgrade process itself is fairly simple and could be a fun weekend project for anyone comfortable operating the single screwdriver/spudger included in the packaging. The whole process takes less than 20 minutes and, unlike most laptops, the innards are accessed through a beautifully-designed magnetic keyboard and trackpad cover, which is easily removed without risking a cracked or broken chassis.

In fact, the overall design of the machine is wonderful, from the sturdiness of its construction, to its lightweight feel, to its responsive keyboard and trackpad. You can bring your own 60W USB-C charger, add colored bezels to the screen, and even put in a new language keyboard if you wish. There are some great quality-of-life features as well, such as a fingerprint reader, webcam shutter, and onboard WiFi 6E support.

But it's the four swappable ports on the sides that are the really clever touch, allowing you to add and swap out USB-C, USB-A, Ethernet, card readers, and display output ports as required. It's a great touch, although Framework was out of stock of many at time of writing. And, as with most laptops, you can install your own DDR4 RAM and PCIe 3.0 SSD drive either now or in the future.

Sadly, Framework doesn't yet produce a laptop with a dedicated graphics processor on board, partly we suspect because of the extra components and cooling required. For now, it's just the integrated Iris Xe graphics available with 96 Execute Units—enough for some basic 720p gaming, but nothing serious.

The Framework Laptop points to a future where we may be able to upgrade our gaming laptop GPU just like we can on our desktop. Razer's popular Blade series, for example, has retained the same chassis and cooling system for many successive generations of Nvidia graphics processors. For now, the Framework Laptop is an excellent machine for regular users who want something they can easily upgrade, and which is a bit more friendly to Planet Earth. **–GUY COCKER**

VERDICT
8

Framework Laptop

+ WORK OF ART Easy and fun to upgrade; external expansion port options; can bring your own components.

– FRAMED FOR MURDER Expensive to upgrade mainboard; no dedicated GPU option; no larger screen option.

$2,049, www.frame.work

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi-Thread (Index)	911	1,628 (78.7%)
CrystalDisk QD32 Sequential Read (MB/s)	2,280	3,435 (50.7%)
CrystalDisk QD32 Sequential Write (MB/s)	316	3,107 (883.2%)
3DMark: Fire Strike (Index)	3,598	4,763 (32.4%)
Rise of the Tomb Raider (fps)	16	20.21 (26.3%)
PCMark 8 (Index)	4,512	4,705 (4.3%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point is the Acer Aspire Vero reviewed in our April 2022 issue, consisting of an Intel Core i7-1195G7, Intel Iris Xe Graphics, 16GB DDR4-3200 RAM, and 512GB SSD. All game tests were performed at 1080p at the highest graphical profile.

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SPECIFICATIONS

CPU	Intel Core i7 1280P
RAM	32GB DDR4-3200MHz
Display	13.5-inch
Native resolution	2256x1500
Storage	1TB Western Digital SNM730 PCIe 4.0
Networking	WiFi 6E, Bluetooth 5.2, Ethernet (optional module)
Ports	4x user-expandable Expansion Cards
OS	Windows 11 Professional
Weight	1.3kg
Dimensions	297 x 229 x 16mm

ASRock RX 6750 XT Phantom Gaming D

Graphics prices falling down, falling down…

A COUPLE OF MONTHS ago, we took our first look at AMD's new RX 6750 XT GPU, courtesy of Asus's ROG Strix model. At the time, pricing was higher than we'd have liked, but things have already moved in the right direction. ASRock's Phantom Gaming D has a lot in common with the Strix card, including the triple fans and large cooler, but prices have dropped by $50—and if you're willing to skip the RGB lighting, ASRock's Challenger D knocks another $100 off the price, making the RX 6750 XT a far more attractive proposition.

Other things have happened in the past couple of months that we wanted to investigate. Specifically, AMD released a DirectX 11 optimized driver after our review, which can improve performance in some cases. Unfortunately, there were times when performance dropped compared to the earlier 22.5.2 drivers. You win some, you lose some.

We tested the ASRock card with the initial release drivers, then updated it to 22.7.1 drivers and tested again. All the earlier driver results were within one percent of the Asus card, basically margin of error, with the Asus holding the overall lead. The updated drivers pushed ASRock ahead by a small margin, but it's the details that are more interesting.

All three ray-tracing games in our suite showed modest 3–5 percent improvements in performance, but the big winner was *Watch Dogs Legion*, which was up to 15 percent faster. Apparently, the DX11-focused drivers also helped DX12 performance in a few games. But it wasn't all sunshine and roses, as performance dropped in some of the other games we tested by up to five percent. Overall, it was a net gain, but AMD still appears to have a few kinks to work on in its drivers.

Compared to Nvidia's RTX 30-series GPUs, the RX 6750 XT nominally competes with the RTX 3070 based on MSRPs: the 3070 starts at $499 and the RX 6750 costs $549. In practice, however, Nvidia's 3070 sells for $549 or more, while the 6750 XT can be had for $499. Meanwhile, the RTX 3060 Ti starts at around $469, making it a closer competitor. Against the 3060 Ti, AMD comes out with a six percent performance lead. Is that enough to give it the win as an overall proposition?

We dig into the details of upscaling technologies elsewhere in this issue (see page 32), and the current state of affairs definitely gives Nvidia's DLSS the edge. It's in more games, it looks better than the competition, and performance on Nvidia cards tends to be better with DLSS than with FSR 2.0. The RTX 3060 Ti also uses less power—ASRock's card averaged 275W while gaming, compared with 206W for the 3060 Ti.

AMD has shown far more willingness to drop its GPU prices to compete, however, and that could ultimately change the verdict. Plus, you get 12GB of VRAM compared to just 8GB on Nvidia's 3060 Ti, 3070, and 3070 Ti. Again, ASRock's lower-tier RX 6750 XT Challenger model spoils the party. It still comes with three fans, plenty for handling a GPU such as the RX 6750 XT, but the real kicker is the boost clocks. The Challenger has a 2618 MHz boost clock, just 5MHz lower than the Phantom Gaming. You wouldn't notice that difference while playing games.

If you love RGB lighting and are willing to pay for it, ASRock's Phantom Gaming D might be what you're after. For those who care more about performance than bling, you can shave $100 off the price without sacrificing performance. Now we just need to see what AMD does with its upcoming RDNA 3 GPUs, and how they stack up to Ada Lovelace. **–JARRED WALTON**

BENCHMARKS

	RX 6750 XT ASRock	RX 6750 XT Asus	RTX 3060 Ti
10 Game Average	**92 / 68**	91 / 67	86 / 65
Borderlands 3	125 / 86	**129 / 88**	99 / 70
Control (DXR)	49 / 30	47 / 29	**63 / 40**
Cyberpunk 2077 (DXR)	28 / 16	26 / 16	**40 / 24**
Far Cry 6	**142 / 103**	141 / **103**	123 / 95
Flight Simulator	82 / 61	84 / 61	**87 / 65**
Forza Horizon 5	111 / **93**	**115 / 93**	94 / 80
Horizon Zero Dawn	**145 / 113**	**145 / 113**	126 / 101
Minecraft (DXR)	36 / 22	35 / 21	**57 / 36**
Red Dead Redemption 2	**97 / 81**	96 / 80	89 / 73
Watch Dogs Legion	**106 / 76**	92 / 69	87 / 65

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x 16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average framerates at 1920x1080 / 2560x1440 ultra, with ray tracing enabled in Control, Cyberpunk, and Minecraft.

VERDICT

7

ASRock RX 6750 XT Phantom Gaming D

+ PHANTOMS Good cooling; 12GB VRAM; prices are dropping.

− POLTERGEIST RGB markup; negligible overclock; drivers are hit and miss.

$619 MSRP, www.asrock.com

SPECIFICATIONS

Architecture	Navi 22
Lithography	TSMC N7
Boost Clock	2623MHz
GPU Cores	2560
Memory	12GB GDDR6
TFLOPS FP32	13.4
Bandwidth	432GBps
TDP	250W
Connectors	HDMI 2.1, 3x DisplayPort 1.4

The ASRock Phantom Gaming occupies three slots with its large heatsink, and has a switch to turn off the LED bling.

BenQ Mobiuz EX3210U

The monitor for all occasions?

THERE CAN BE MANY factors to consider when choosing a display, depending on whether you're using your PC for work and whether that work relies on a color-accurate screen. If you're looking at a gaming monitor, then chances are it'll prioritize a high refresh rate over color accuracy. Not so with BenQ with the Mobiuz EX3210U, which offers a monitor with 4K resolution, a gamer-friendly 144Hz refresh rate, and a wide color range. So does that make the EX3210U the ultimate all-in-one monitor?

32-inch monitors are often considered right on the cusp of being too large for a desk setup, but they deserve a look if you can mount one properly. Depending on your layout, this could double up as an internet TV, or a gaming monitor, or just a general display for daily PC procrastination. On the whole, this monitor feels sturdy and well put together, with a two-piece stand to evenly disperse its weight. It has a 5° tilt, swivels left and right at up to 15°, and can be vertically adjusted too.

The back of the monitor features a white shell with Mobiuz branding, subtle RGB lighting, and True Sound by treVolo. These speakers offer a warm sound, which is good enough for a monitor and general media consumption. If you expect something with detailed high-ends, you may be disappointed, but on the whole, they perform admirably. Below this is where all of the connectivity options lie, including two HDMI 2.1 ports and a DisplayPort 1.4 socket. An extra DisplayPort and maybe a USB-C would have been welcome, but at least what's here is neatly covered by a shroud.

At the front, the monitor has thin bezels around the sides and top of the display with a thicker chin housing the Mobiuz EX3210U's HDRi sensor underneath. This HDRi functionality is seen across BenQ displays—the 'i' stands for intelligence as the sensor reads your room's ambiance and automatically adapts the displayed HDR accordingly. Testing under different lighting conditions, it works rapidly to correct the dynamic range to suit and is an impressive feature overall.

However, the main attraction here is the 3840x2160 resolution IPS panel—this 4K display is a thing of beauty. Without even diving deep into the color settings, this screen is full of life and has a strong contrast without harsh sharp edges. With the HDRi mode switched on, colors appear bold but not over-saturated and it features a wide color gamut of 98 percent P3, delivering the vibrancy that makes this screen look so crisp. For a non-VA display, the dark colors are rich and give great depth of field in gaming scenarios. Viewing angles are also impressive and the screen isn't too reflective under direct light. One slight negative is that the display only offers 300 nits of brightness.

The snappy 144Hz refresh rate with a response time of 1ms makes it ideally suited to gaming, especially with its vivid and immersive display. With a 32-inch 4K monitor, velvety smooth resolution, wide color gamut, fast response time, and that 144Hz refresh rate, one of the main issues will be finding a PC that can get the most out of this BenQ screen. Ideally you want enough grunt to run everything on maximum settings to make the most of it.

All this does come at a price though, and, at $1100, it's a fairly steep one. But if you can afford the cost, then this is a display that can do it all. It features a decent speaker system and even includes a microphone too. –**SAM LEWIS**

VERDICT
9

BenQ Mobiuz EX3210U 32-inch

+ SILVER SCREEN 4K resolution; snappy refresh rate; gorgeous color range; HDRi support; remote included.

– BLUE SCREEN No USB Type-C; only 300 nits of brightness.

$1100, www.benq.com

SPECIFICATIONS

Panel size	32-inch
Panel type	IPS
Resolution	3840 x 2160
Brightness	300nits (peak HDR 600nits)
Contrast	1000:1
Pixel response	1ms
Color gamut	98% P3
Refresh rate	144Hz
Connectivity	2 x HDMI 2.1, 1x DisplayPort 1.4, 1 x USB Type-B (upstream), 4 x USB Type-A 3.0 (downstream), 3.5mm auxiliary jack

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The only issue with
the BenQ Mobiuz
EX3210U is finding a
PC to keep up with it.

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Nubia Redmagic 7S Pro

Great for gaming, merely OK for everything else

GAMING SMARTPHONES do for mobiles what high-end PCs do for computing—max out the performance and offer more customization options than anyone really needs. There are now more of these devices than ever, including ones from traditional PC brands such as Asus and Lenovo. Redmagic may be less well known than those two, but it's an offshoot of Chinese phone giant ZTE, and this is the sixth generation of its gaming phone lineup, so the company has had plenty of experience in honing its offerings.

The 7S Pro builds on the 7 Pro that we featured as an Editor's Pick a few months ago in our June 2022 issue, with a faster processor, namely the Snapdragon 8+ Gen 1 and… er, that's about it. There are other minor tweaks, such as the air vent on the rear, which now sucks air in rather than blowing hot air out onto your fingers, while the RAM on the standard 256GB model we're reviewing has, strangely, gone down from 16GB to 12GB.

For gaming phone aficionados, the headline here is one you'll have read countless times before: it's fantastic for gaming, but a compromise for most other things. If your top priority is playing *Genshin Impact* at max settings at a rock solid 60 frames per second—something that even the Samsung Galaxy S22 Ultra can't do—then this is the phone for you. However, if you're looking for a good camera, water resistance, or wireless charging, then you'll have to opt for a more traditional smartphone.

The Snapdragon 8+ Gen 1 is the fastest mobile chip available that isn't made by Apple, with a Geekbench 5 single-core score of 1317 and a multi-core score of 4167, which is leaderboard-topping stuff. That said, it's only a seven percent increase over the previous-generation chip, so not worth an upgrade over the 7 Pro. All of the games we tried maxed out at their highest settings and framerate, including 120fps in *Real Racing 3* and *Vainglory*.

The excessive nature of the phone's specifications also means it's a joy to use in everyday operation. The fingerprint scanner is incredibly quick to unlock the phone, general navigation is extremely snappy, and you can keep multiple applications open without any kind of slowdown.

It helps that the screen is also excellent, although, at 120Hz, it's lagging behind the ROG Phone 6's 165Hz display. It's also not a QHD display but an "FHD+" 1080x2400 one, although detail and color accuracy are excellent. It doesn't go that bright at 600 nits (the S22 Ultra goes up to 1,750), so you won't be gaming on a bright summer's day, but then why would you want to do that anyway?

SNAP DECISIONS

Camera performance is where things start to fall down. The rear camera unit features a 64MP + 8MP + 2MP array. The main lens is fine in well-lit environments, but isn't as impressive in any other conditions, while the macro and wide lenses are best avoided completely. The 16MP selfie camera is embedded under the screen, which means the display is uninterrupted for gaming but results in smeary photos and videos with lights that produce a distracting bloom. We're optimistic that one day a manufacturer will release a gaming phone with good cameras, but that day isn't today.

Another gripe is the 5000mAh battery, which is decent, but some way off the 6000mAh rating found on other gaming phones such as the ROG Phone 6. Disappointingly, the max charging rate of the phone and included charger is 65W, rather than the 135W you get on the equivalent phone in China. We also wish the charging port was located on the side of the phone, rather than on the bottom, where it gets in the way of your fingers when gaming in landscape mode. There is a physical headphone port though, which will please audio purists.

Our test configuration of the Redmagic 7S Pro (12GB, 256GB) costs $729, which is relatively cheap given the state-of-the-art components inside. It's also slightly less than the previous gen 7 Pro, and a lot less than the equivalent ROG Phone 6 ($999). Judged on that, it's a great value gaming phone, but if your top priority is anything other than gaming, you'll want to look elsewhere. **–GUY COCKER**

VERDICT
7

Nubia Redmagic 7S Pro

+ **MASTER** Great screen, unbeatable performance, responsive inputs.

− **AMATEUR** Poor cameras, no side-mounted USB port, reduced charging speed.

$729, www.redmagic.gg

SPECIFICATIONS

Charging	65W GaN
Operating system	Android 12
Processor	Snapdragon 8+ Gen 1
RAM	12GB
Storage	256GB
Battery	5000mAh
Dimensions	166.27mm x 77.1mm x 9.98mm
Weight	235g

Razer Barracuda Pro

Wireless gaming and lifestyle cans—and a compromise on both

HEADPHONE manufacturers pitch a different set of cans for whatever we're doing—one pair for using at your computer, another for when you're out and about, and yet another for when you go to the gym. With the Razer Barracuda Pro, Razer has had the bright idea of combining PC headphones with lifestyle headphones so you can wear the same pair whether you're playing *Doom Eternal* or walking into town.

As with most of Razer's products, first impressions are great. The headphones are housed inside a sturdy and well-made carry case, which also stores the USB-C dongle and charging cable inside a magnetically-sealed compartment. Everything is matte-black and cleanly designed, and the headphones look more like the popular Sony WH-1000XM4 lifestyle cans than most gamer-centric models, Razer's included.

The carry case is large compared with the equivalent cases of popular lifestyle models. Unlike Sony's model, the Barracuda Pros don't fold up, instead, the earcups turn 90 degrees so they can go flat into the case. The case will slide into a laptop bag or backpack, is sturdy, and is made from premium materials, but will take up a lot of space if you're trying to pack light for a flight, for example.

The headphones themselves are extremely comfortable, thanks to their lightweight design and soft memory foam ear cushions. They're not quite at the level of 'forget you're wearing them' comfortable, but they're a lot better than most bulky PC headsets.

The headphones use a tiny USB-C transmitter that's smaller than most USB pen drives. This allows it to be plugged directly into an Android phone or a Nintendo Switch console, while a USB-A adaptor is included for PC and PlayStation users. The feature we really liked was the ability to connect to Razer's receiver on the PC, while simultaneously staying paired to your mobile device over Bluetooth. This means you can take calls at the touch of a button without having to stop whatever you're doing on your PC. Wireless connectivity is excellent from both the dongle and Bluetooth, which can't be taken for granted with gaming headphones. We were able to walk around the home freely without experiencing any interference or dropouts.

Being lifestyle headphones, they come with Active Noise Cancellation (ANC), the levels of which you can control using a button on the device, or from within the Razer Audio app. It can be switched off completely, set to its highest level, or placed in 'Ambient' mode where you can still hear noise from the outside world, such as traffic. Razer's ANC isn't going to trouble Sony or Bose when it comes to the business traveler crowd, but it did a good job of drowning out the noise of our mechanical keyboard completely.

Things fall down when it comes to audio quality. It's crisp and clear but is found lacking in terms of bass when compared to equivalent-price lifestyle headphones. This doesn't really impact on podcast listening or YouTube viewing, but it does limit the enjoyment of music and gaming, as it's unable to provide the presence that you would expect from immersive entertainment.

The same is true of the dual microphones, which are built into the headset. This is a good thing given its dual role as a lifestyle model, but we didn't find it effective for voice calls during the day or team chat in the evening. For PC users, that might not be a big deal if you have a separate mic at your desk, but it doesn't really make it an effective device for taking calls on the go.

The Barracuda Pro is a noble attempt to make a pair of gaming headphones that you can also take with you on the go. From a design standpoint, they deliver on the remit—they're lightweight, comfortable, and look good enough to wear out-and-about. But they are also too compromised on the core features of audio and voice playback to be able to recommend. Sometimes you just can't have it all. **–GUY COCKER**

VERDICT
6

Razer Barracuda Pro

+ HI-FI Fantastic wireless range, comfortable lightweight design, brilliant battery life.

− LO-FI Average audio, microphone and active noise cancellation quality.

$249, www.razer.com

SPECIFICATIONS

Compatibility	PC, PlayStation, Switch, Mobile (Android & iOS)
Virtual Surround	THX Spatial Audio
Frequency Response	20 Hz – 20 kHz
Driver Size	50 mm
Noise Cancellation	Active
Connection Types	USB-C Wireless Dongle, Bluetooth 5.2
Battery Life	40 hours
Weight	340g
Diameter (inner earcup)	62mm x 42mm

Corsair K70 Pro Mini Wireless

Is this small and quirky keyboard worthy of its hefty price tag?

IN THE (CHERRY MX) red corner, weighing in at just 1.42lbs, we have the latest contender from Corsair's K70 keyboard range. As a 60 percent keyboard, does it pack a mighty punch or will it throw in the towel? Judging by the price tag alone, we're unsure how this fight will go—it costs more than the full-sized K70 RGB Pro we reviewed recently, which arguably has more versatility. On the other hand, the 60 percent wireless form factor is a big favorite in the gaming scene. So, is less actually more?

Straight out of the box, the design of the K70 Pro Mini Wireless feels sturdy, giving you the feeling of a good quality product. It is evenly weighted and features a rubber bar underneath and rubber around the feet to keep it in place on your desk. The feet only have one level of adjustment, which although it does give you a comfortable angle for typing, doesn't offer much variety.

Round the back of the board is where you find a USB dongle for the Slipstream wireless connectivity. Bluetooth is also available and there's a USB C port on the back next to the power switch. Unfortunately, this USB C port is sunken into the board, which works great for Corsair cables but possibly not if you fancy switching it for a 90° custom cable.

The Corsair K70 Pro Mini Wireless is a 60 percent format, meaning it lacks a number pad, functionality keys, standard arrow keys, and typical media control switches. This does have its perks as the keyboard is only 11.6-inches wide, making it ideal for gamers with limited desk space. It also looks great in minimal setups and the wireless functionality gives it an advantage in that you can store it away easily without having a mess of tangled cables on your desk.

Customization is a big factor in this smallest member of the K70 family. Round the back, you can replace what Corsair calls an interchangeable accent bar. It features customizable key caps and hot-swappable switches, which are a must on a premium keyboard. It gives the board a longer life span and allows the user the option of having different setups based on different uses. Saying that, we don't necessarily recommend swapping the keycaps as these feature all the FN control symbols. Unless you know the format off by heart, this could be an issue.

SPACED OUT

In the box, you get all the tools you need to customize your board further down the line, a keycap with the Corsair logo on, and also a replacement space bar, which we added straight away. This features a textured design that allows for more of the RGB backlighting to be visible.

Talking of the RGB, it shines evenly throughout the keyboard and glows around the bottom too. With this on, you can expect up to 32 hours of battery life, and without the fancy light show, you can get an impressive 200 hours of power.

But what is it like to use? Both wired and wirelessly, this keyboard has impressive performance with a polling rate of up to 8,000Hz and a sub-1ms wireless connection, thanks to Corsair's Slipstream technology, so it's certainly speedy enough for a gaming keyboard. It's worth noting that, regardless of your connectivity choice, the power switch must be on to use the keyboard—yes, even in wired mode.

The keycaps are an improvement on the K70 RGB Pro we featured recently. Although they are still Doubleshot PCB, they feel less rough around the edges. It's clear to see the functionality symbols on these keycaps too. This mechanical board comes with either Cherry MX Speed or Red switches from the store and we got the latter in our review sample. Although these are smooth linear switches, the overall feel is mixed across the keyboard. Certain keys seem to have more resistance than others, which isn't ideal performance from a keyboard that costs just under $180.

The reality is that this wireless 60 percent format is a great size for competitive gamers. Overall, the keyboard has plenty of features, good performance, and a sturdy aluminum frame to support it. The RGB is strong and adjustable on the fly, there are plenty of customization options available and the keyboard is solidly constructed. However, with a price tag like this, you'd expect everything to be the best of the best. With plenty of other cheaper alternatives on the market achieving similar features and performance, it makes it harder for us to recommend the K70 Pro Mini Wireless. **–SAM LEWIS**

VERDICT
7

Corsair K70 Pro Mini Wireless Keyboard

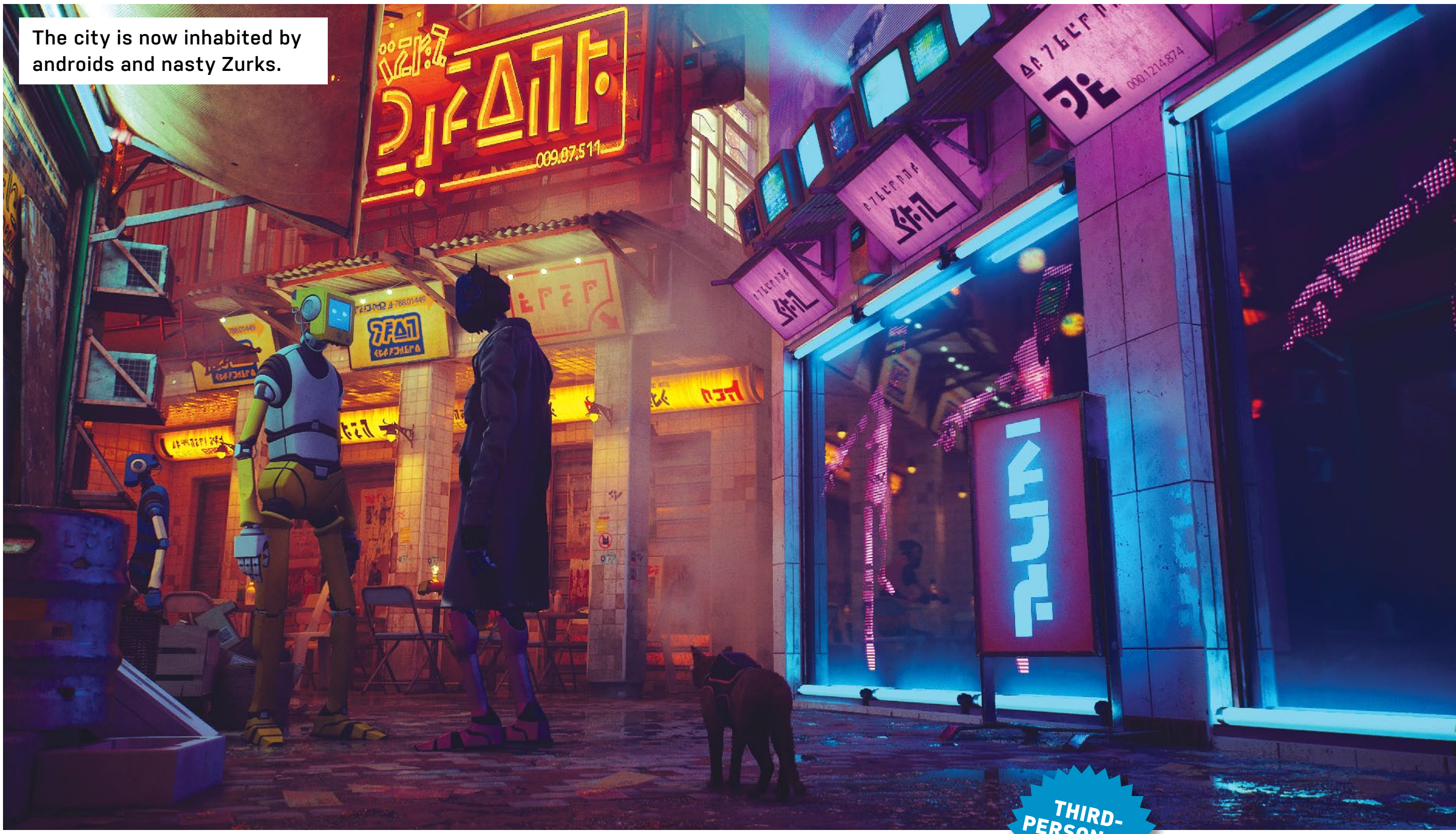
PRO Cherry MX Red switches; hot swappable keys; removable cable; sturdy feel.

SEMI-PRO No USB pass-through; steep price; some resistance on key presses.

$180, www.corsair.com

SPECIFICATIONS

Switches	Cherry MX Red
Switch durability	100 million+ presses
Design style	60% Mechanical
Connection	USB 3.0 Type-C to Type-A, wireless sub-1ms Slipstream, low latency Bluetooth
Polling rate	Up to 8,000Hz USB Hyper-polling w/ Corsair AXON
Battery life	Up to 32 hours w/ RGB, Up to 200 hours w/o RGB
Wrist-rest	N/A
Weight	1.42lbs



The city is now inhabited by androids and nasty Zurks.

THIRD-PERSON CAT ADVENTURE GAME

Stray

Platform gaming meets the ultimate protagonist

WE'VE PLAYED as some strange things in our time. A bipedal cow, the manifestation of a sun goddess as a wolf, any number of angry bald white men. But a simple cat? That's a new one. Although, haven't we been playing as cats in games all along, scrambling over platforms, and swatting things out of our way?

This cat does all that and has a cute 'miaow on request' button. A slim and gingery (there's no character customization, which surely must lose the game a point or two) member of a colony, or family, of kitties living in industrial ruins long since returned to nature. While huge rusted pipes and slabs of concrete are the order of the day, they're covered in moss, creepers, and all the usual signs of abandonment.

And that's how the game starts, your feline gang running free in the ruins until you miss a jump and tumble into a rubbish-strewn underground tunnel.

Now, a note for the soft-hearted. Yes, kitty gets hurt. But she quickly shrugs it off, and most of the game is spent in free-flow exploration mode. Your feline avatar is intelligent enough not to walk off the edge of platforms, and will only attempt a jump when there's somewhere to land, telegraphed by a button prompt. She's the master of her environment, able to bat paint cans off walls to smash glass just like any other cat and capable of moving objects around in her mouth too.

There are, however, nasty little creatures known as Zurks in the city that, given the chance, will jump on kitty and, well, end the game. They're easily avoided, can be shaken off and eventually shot at, and there's an instant restart if they do swamp you, but it can be a wrench when it first happens. The basic Zurk is a cross between *Half-Life*'s headcrab, a plump tardigrade, and an oven-ready chicken. The areas they have colonized are marked by strings of goo, and their beaks (if that's what they are) are sharp enough to eat through metal.

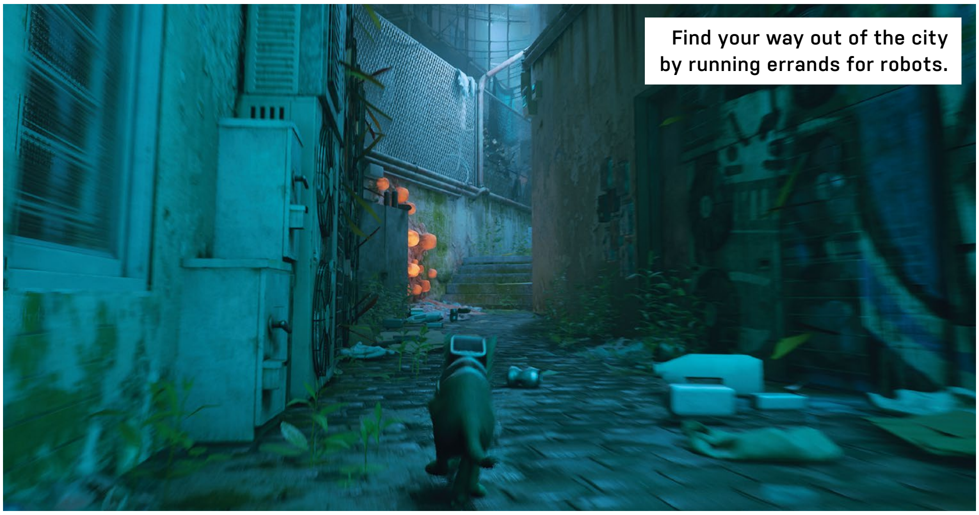
But before that, and all through the game, you have the simple joy of movement as a cat. The way she sashays like a supermodel, tail aloft, along the alleyways, makes a perfect jump to the top of a fence, and from there to a corrugated tin roof. The way she blunders into physics objects like a vase or the balls on a pool table, the playful way she reacts to butterflies, scratches the carpets, and, of course, knocks over the paint cans. The developers know you're going to want to topple them, so they lined up six for you the first time you encounter them, maximizing the satisfaction.

CAT-LIKE GRACE

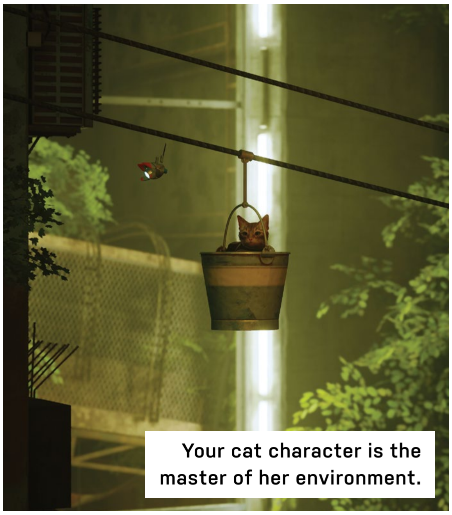
Her refusal to jump without having a place to land is cat-like too, her movements have all the rhythm and grace you'd expect from a cat, even when being controlled by an ape with a bit of plastic. When she's asked to wear a harness later in the game, she twists and stoops her belly to the floor in an attempt to get out of it—as if you'd just dressed her in a fetching Christmas jumper. She doesn't mind the harness after that moment, which is a good thing.

The city isn't completely abandoned, you see. After an intro/tutorial following projected arrows and 'help me' messages, you discover it's alive with androids, living out a parody of human life hundreds of years after the Soft Ones

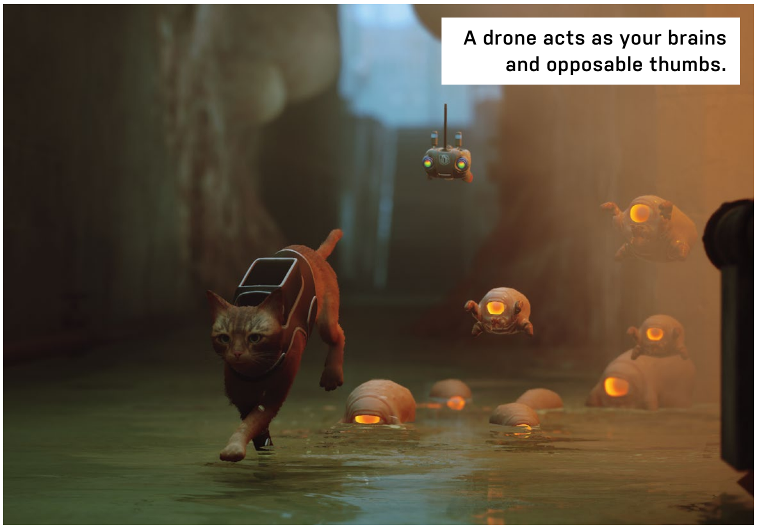
© ANNAPURNA INTERACTIVE



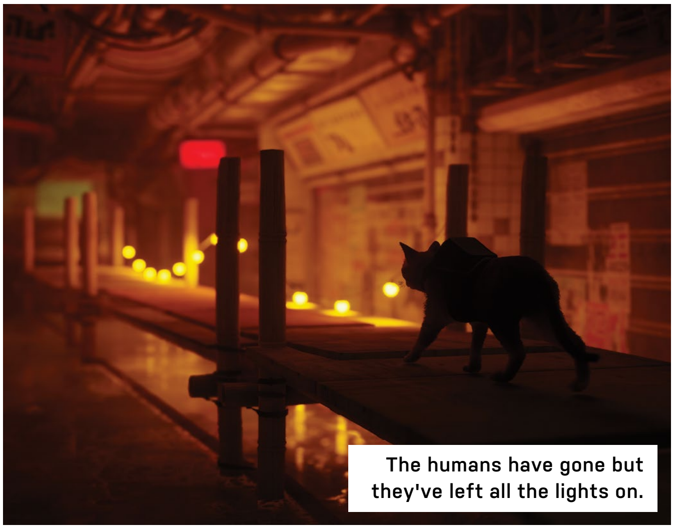
Find your way out of the city by running errands for robots.



Your cat character is the master of her environment.



A drone acts as your brains and opposable thumbs.



The humans have gone but they've left all the lights on.

left. They huddle under blankets, stare at flickering screens, knit scarves that go on for miles (just for something to do) and run from organic life as unfamiliar and likely to be a Zurk. Others want to leave, but can't. They're tragic creations, something underlined further on in the game when a vision of their future is unfolded for you.

While you busy yourself trying to find your own way out of the city, running errands for robots—mainly fetch quests that are repaid with information—the city is revealed to be a nest of puzzles that need solving. One strange side-effect of the human desertion is that all the light-up signs and TV screens seem to have kept working, sometimes flashing away randomly, cycling through a corrupted memory of their once-brilliant display.

The dead city is a dark place, and your passage through it traces an ascent into sunshine (or are they spotlights?), but before you get there, you'll need to seek out its tightest corners and explore every alleyway, hunting for clues.

Throughout the game, you're accompanied by a drone companion that acts as the brains and opposable thumbs you lack. It's got a neat trick of 'digitizing' objects so they can be stored in your inventory instead of outfitting you with pockets, a light for dark places, and a translation ability for reading signs. Getting back its memories is a part of the exploration, a journey as much for the drone as for you, and the tightness with which the stories of robots and city are woven together is beautifully done.

EMOTIONAL ATTACHMENT

Sometimes *Stray* can remind you of *Inside*, Playdead's tale of a boy on the run, though it doesn't have that game's rampaging, cathartic ending. Other times it's like your favorite platform game, such as the bits in *Half-Life 2* where you create a seesaw from building materials to get over a jump you can't make. There's a degree of emotional attachment to the protagonist for cat lovers, but also anyone with normal levels of empathy, and playing as a cat never stops being entertaining. There's something about choosing your path in the absolute certainty that you'll land every jump—occasional mad dashes to avoid Zurks aside—that's empowering.

Through feline eyes, you're the king of the dead city. Its handy bucket-equipped zip wires and strategically placed cans of paint are your playthings. And while it's not a long or particularly complex game, it leaves an impression that lasts long after you've curled up somewhere cozy for the night. **–IAN EVENDEN**

VERDICT 8

Stray

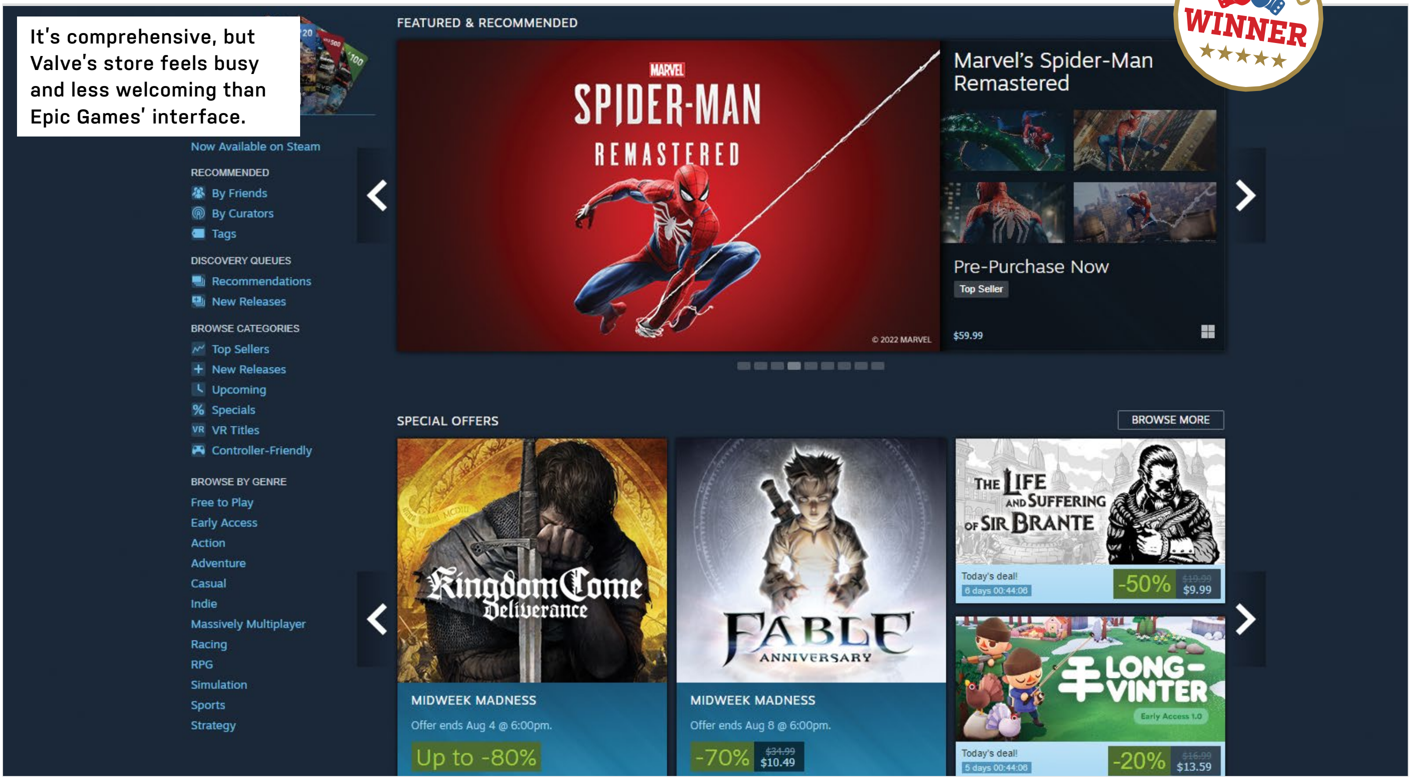
+ KITTY Exceptional movement and traversal; moments of sadness and triumph.

− LITTER No character creator; instafail stealth sequences; dog-lovers may feel left out.

RECOMMENDED SPECS CPU, i5-8500, R5 2600. RAM, 8GB. GPU, GTX780, R9 290X.

$30, stray.game, E-rated

HEAD TO HEAD WINNER ★★★★★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By Friends
By Curators
Tags
DISCOVERY QUEUES
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It's comprehensive, but Valve's store feels busy and less welcoming than Epic Games' interface.

Steam vs. Epic Games Launcher

Which is the better place for PC gaming in 2022?

IT'S HARD TO BELIEVE, but Epic's Game Store has now been going for nearly four years, during which time it has given those who log in weekly literally hundreds of premium games to enjoy for free. At over 19 years old, Steam has been going much longer, and while it's got plenty of free-to-play offerings, owner Valve has instead plowed its own furrow in the hardware space, notably the Steam Deck, which allows users to play a decent amount of its games on-the-go. But which one is the best place for you to buy, store, and play your games in 2022?

Let's start by covering the areas where the two platforms have converged or are similar. Epic has recently enabled Online Services crossplay support so that, in theory, games released on Epic Games Store can play online with those on other stores, meaning you won't have to buy the game twice to play with friends.

Each application will also download games to a destination of your choice, and automatically keep them up to date. Both also allow you to keep friends lists, although only Epic allows you to import friends from Steam, not the other way round. They also both allow you to create Wishlists, store your save games for free in the Cloud, and throttle downloads so you don't choke your network.

Other than that, the two platforms are very different in terms of their offerings, design, and approaches. For breadth of content, the winner has to be Steam, with its over 50,000 titles at the time of writing. Sure, the majority of those won't be worth the internet bandwidth, let alone the time playing, but its catalog dwarfs Epic's 500-or-so titles.

However, many gamers would say it's quality that counts, and thankfully there are some stone-cold classics available on both platforms. Valve games, such as *Team Fortress*, and Epic games, including *Fortnite*, are exclusive to their respective platforms, but a lot of third parties such as PlayStation Studios, Rockstar, and Sega are now making their games available day-and-date on both stores.

CONFUSING POLICIES

Frustratingly though, many major publishers aren't, and some also repeatedly change their policies just to confuse everyone. Activision, for example, used to put its games on Steam, then took a few years off—it is now putting future titles on Steam, but not Epic Games. It's a similar story for Acti's potential new owner Microsoft. EA puts its games on Steam, but is only now coming to Epic for the first time with its 2023 sports games. Ubisoft, meanwhile, only puts its games on Epic, not Steam, while Capcom only puts its games on Steam, not Epic.

It's all pretty confusing, but Steam wins points here by allowing you to use it as a launcher for any game residing on your PC's hard drive by simply adding the game's '.exe' file into its library. It's a neat feature that further cements Steam's reputation as the go-to launcher for your entire game library, and is a feature sorely lacking from Epic Games' launcher.

When it comes to pricing, there's not much to differentiate between the two stores. *FIFA 23*, *Stalker 2*, and *Spider-Man: Remastered* were the same price across both at time of writing. This is normally the case for sales too, with publishers coordinating any discount events across stores to ensure parity for players wherever they choose to purchase. While Steam's sale events can be great and are famed for giving impulsive buyers a 'library of shame' in terms of unplayed games, we have to give credit to Epic's discount schemes whereby they often

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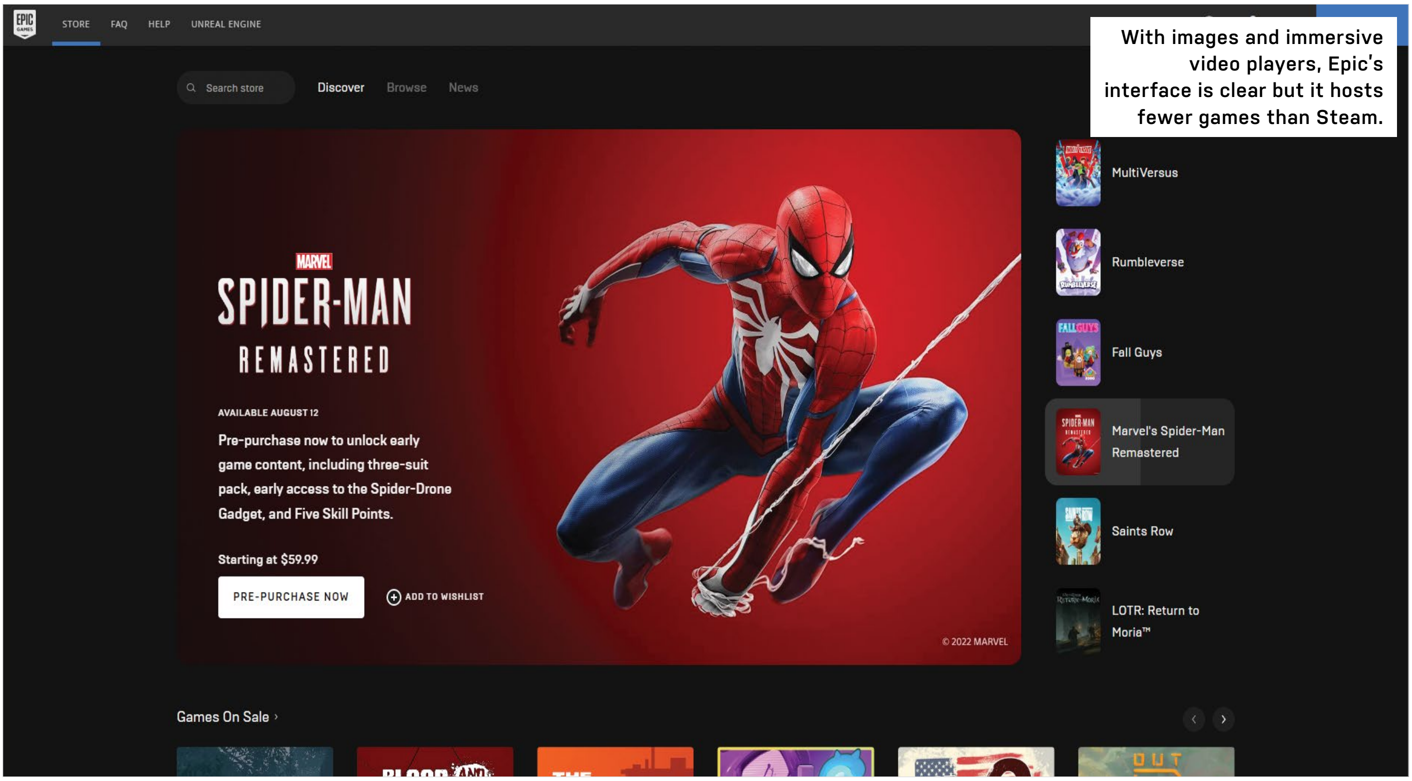

Pre-purchase now to unlock early game content, including three-suit pack, early access to the Spider-Drone Gadget, and Five Skill Points.

Starting at $59.99

With images and immersive video players, Epic's interface is clear but it hosts fewer games than Steam.

run excellent promotions and then offer unlimited $10 coupons on top for games priced at $15 or more. In the past, this has allowed us to purchase games such as *Watch Dogs: Legion*, *Tony Hawk's Pro Skater 1+2*, and *Immortals: Fenyx Rising* for between $5-$10, which is an absolute steal. So if you're a bargain-loving gamer, you really need to be keeping an eye on both platforms.

FREE GAMES

Free is even better than cheap, though, and it's here that Epic Games deserves recognition for being one of the best things to ever happen to PC gaming. If you'd set a reminder to log into Epic once a week over the last few years, you'd have been able to claim *Metro Last Light Redux*, *Control*, *Grand Theft Auto V*, *Shadow of the Tomb Raider*, *Borderlands 3*, *Overcooked! 2* and many other brilliant PC games for absolutely nothing.

Sure, the games aren't always of this caliber and they are occasionally repeated, but a frugal gamer could have reasonably kept themselves entertained on the Epic Games Store for the last few years without spending a dime. True, the freebie tap could be turned off by Epic at any moment, in which case we had a good run. But as long as it keeps running, you need to have its launcher installed on your PC. Steam can't compete, although to be frank it doesn't need to, because it has a much larger userbase than Epic.

In terms of the interface, the two stores are reflections of the game libraries they host. Epic is clean and pretty, while Steam is cluttered and utilitarian. There are loads of ways to browse Steam, including neat features like seeing what your friends are playing, plus a mountain of user reviews to help judge the quality. But while there are 271k reviews for *Destiny 2* alone, one of the top ones was "Please add sex", which gives you an idea of the quality of critique on offer. Epic puts more of an emphasis on professional reviews and, as one such publication, we would recommend this approach. Its store is all nicely presented thumbnails and then a satisfyingly immersive emphasis on video when you click through to a game.

For gamers who care about creators making money from their endeavors, then Epic Games is the way to go. Epic takes just 12 percent of the revenue made through its store, compared to Steam's 20-30 percent, depending on how well the game sells (the more it sells, the less Valve takes).

You may remember Epic's well-publicized court battle with Apple over the revenue it makes through its App Store. It lost the case, perhaps explaining why Valve is still able to charge comparatively high rates. If there's an indie developer you love that's selling its game on both platforms, rewarding them with a purchase through Epic means they see around $1 more per $10 spent.

Epic has made big inroads into the PC storefront space in recent years and spent big doing so. Reports last year claimed the company burned through $11m paying creators to offer their games for free, earning 5m new users in the process. But in 2022, it still feels as though Steam is the default games store for PC gamers and the better option of the two in terms of managing a library. We hope Epic continues to build on a strong start and offers some serious competition to Valve, but for now, Steam is still king of the PC game stores. **–GUY COCKER**

VERDICT
9
KICK ASS!

Steam

+ HIGH PRESSURE Insane number of games; launches games from other platforms; you can see what friends are playing most.

– LOW PRESSURE Busy and cluttered interface; fewer quality free games; low-quality user reviews.

$free, www.steampowered.com

VERDICT
8

Epic Games Launcher

+ EPIC Weekly free premium games; clean interface; great coupons and sales.

– INSIGNIFICANT Limited game library; unable to launch other stores' games; fewer social features.

$free, www.epicgames.com

© EPIC GAMES

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Mismatched Modules
> Sitting on the periphery
> Almighty AMD

Sale of the century

In your console killer feature (August 2022 issue), you used the Asus RTX 3070Ti TUF GPU with a street price of $900. I just got that very same card from Best Buy on a Prime Day sale for nearly half that, at $499!

Also, on Sam's Build It in the same issue (Page 66), he had a Ryzen 9 CPU along with an RX 6650 XT GPU—that's quite some mismatch. I understand the logistics issues you face right now, but perhaps when you do these builds, a word about the mismatch might be appropriate. I remember previous editors screaming about such mismatches... all in all, a great issue though.

–R. Matlow

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:

I, for one, cannot wait for the day when we can finally drop the 'street price' columns from our Specifications tables! Not only from a formatting perspective—I'm a stickler for a clean spreadsheet—but also from a mathematical perspective so we no longer need to calculate both a 'retail' and 'real world' price for our builds.

As you noted with your RTX graphics card purchase, we're pretty much back to RRP price territory now and with sale events, you can even go under that—unheard of just a few months ago. We're subject to lead times here on *Maximum PC* so there's a little catching up to do—I'm writing this at the beginning of August, but you won't read it until mid-September, although subscribers do get their issues earlier (just one good reason to subscribe, check out page 42).

As for component mismatch, this is another thing that should be getting better as the supply chain returns to normal, although you make a fair point on making this more obvious in our builds. Our plan for the next couple of months is to focus on 'value' builds, with a sub-$1,000 gaming PC and an Intel vs. AMD Build It Special, before we hopefully start to see new high-end CPUs and GPUs hitting the market at the end of the year.

This season's must-have accessories

Would you ever be willing to expand on your Blueprints by adding peripheral suggestions?

For example, in the Budget Build, can a suggested gaming and production monitor be listed? Is it better to spend more on a superior monitor, CPU, or GPU? Likewise, in the midrange, is it smart to spend more on a monitor to improve user experience?

I realize I could look back in previous issues, but because *Maximum PC* doesn't have a yearly index of articles, I would have to laboriously go through each issue... that seems like a great project for the intern!

–D. Pitney

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:

We've been trying to do more peripheral-based spreads as part of our bigger builds recently. For example, when I did the couch gaming special (August 2022 issue), I had a great time picking out the best wireless gaming accessories to go with it. It's something Sam's planning to do with his sub-$1,000 gaming PC next issue as well, by picking out the best value additions you can make to such a system.

In terms of adding this to our monthly Blueprints, that may be of help to some readers, but I wouldn't want to confuse others by adding accessories they might not need to the price. Also, it may not seem like it, but Blueprints is a big monthly job for our writer Sam, who has to research all the latest components as well as price drops and update accordingly. Throw in a few monitors, keyboards, and mice and we might soon send him a little loopy!

Ryzen like a phoenix

I wanted to say what a spectacular article Jeremy Laird wrote on AMD's resurrection (July 2022 issue). I have been absolutely fascinated with what AMD has been able to do with the Ryzen CPU series. His article covered AMD from the early days until today, which helped me see the whole picture of the company's evolution. For most of its history, I've looked at AMD as a weak

↘ submit your questions to: editor@maximumpc.com

player in the CPU business and never a serious threat to Intel. One thing the article makes clear is that the right people coming together made this turnaround happen—very exciting. Thanks, Jeremy!
–W. LeDuc

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: I passed your feedback on to Jeremy, who was pleased you enjoyed his feature. AMD's turnaround is indeed one of the most interesting tech stories over the past few years, and while its stock price is down around 50 percent from its all-time high at the end of 2021, it's still up 650 percent over the last five years. This makes CEO Lisa Su one of the most impressive tech leaders in the industry, based on performance.

For consumers who just care about the products, AMD has taken the fight to Intel, producing chips that constantly outperform the competition while being significantly cheaper and, as a result, has single-handedly forced Team Blue to up its game. With the next-gen Zen 5 chips due imminently, we'll soon get a picture of how they'll compete over the next couple of years.

Framework homework

How do you decide what computers to test? I just found an interesting computer company called Framework Laptop that I'd never heard of before and wondered if you had ever heard of the brand. I'm intrigued by the do-it-yourself idea and the ease of repair and upgradeability of the concept. I know it's not a gaming computer, but some of your readers might be interested.

I decided to take the plunge and order a unit for delivery with the following specs: Intel i7-1185G7, 64 GB RAM, USB-C and three USB-A ports, and a 2TB WD_BLACK SN850 NVMe hard drive. I will also order the Ethernet adaptor when it becomes available.

Now all I have to do is upgrade my 4790K desktop when Gen 14 or 15 comes out. I'm in no hurry, I just needed a new small computer with some oomph when my little Asus T100 died suddenly and this looked like a nice option. Looking forward to my next issue of *Maximum PC*.
–E. C. Knack

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Great minds think alike because you will find our review of the Framework Laptop on page 80 of this issue. We can't take all the credit, though, as our good friends at *PC Gamer* had this laptop in the labs, with writer Dave James upgrading it from an 11th-gen Intel chipset to a 12th-gen model before we took a look at it.

We won't spoil the review, but either way, it's a fantastic idea to build a laptop in this way. Take my last two gaming laptops, for example—I moved from the Lenovo Legion 5 Pro (2021) to the Legion 5i Pro (2022) and all that really changed were the internals. The chassis, screen, keyboard, and ports were all pretty much identical. So it's a waste to have to buy a whole new laptop just to upgrade.

We've mentioned in these pages our concerns about the rising energy use of the latest graphics cards. Another environmental concern is the amount of waste that non-upgradeable systems are creating. It's great to see Framework doing something about it.

Charity begins at home

I've been a subscriber to *Maximum PC* since the first issue of *Boot* magazine. After reading the "Charity case" letter in the August issue, I thought I would drop you a line and let you know that there are numerous local charitable organizations that collect and re-distribute used computers and electronic equipment.

For the past six years, I've worked with a Schenectady, NY, based organization called 'GE Elfun Computer Rehab' (https://www.computerrehab.org/) that was founded in 1993 and is staffed entirely by retirees, who range in age from mid-60s to over 80 years old.

We take in used equipment from individual donors and large and small businesses, refurbish and/or repair, if possible, and then donate to non-profits at essentially no cost, except for an administrative fee if a Microsoft OS and Office are required.

Most of our equipment comes to us locally, but we also have some corporate sources in the greater northeast. Most of our donations are also local but, again, other charitable organizations have distributed systems internationally to third-world countries.

I'm aware of a couple of other organizations in other states that re-purpose equipment, so I think an internet search could probably turn up various local organizations.

We also find that some people hold onto their non-used computers for a long time. Recently, we received an original IBM XT and some other generic brands of that vintage.

Thanks for a great magazine. Keep up the good work. **–R. Wroczynski**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thank you for letting us know about another charity that takes computer donations, and thanks for your hard work in repairing these machines and getting them to places where they can do some good.

Benchmark busting

Would it be possible to do a small comparison between 'the builds' in the Blueprints section of your magazine? Something along the lines of Zero-Point tests comparing each of the three tiers, but on a much smaller scale? Preferably just one comparison, and not just graphics but a comparison value of raw number-crunching also.
–Jerry

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: While we research and update each of the blueprints each month, they are just that sadly: blueprints. We don't actually create these builds, because to do so would require us to get each of the components into the lab, which is often not possible.

Sure, we've reviewed or tested most of the components that we recommend in these builds at some point in the past, hence our ability to recommend them. But, sadly, we're not able to test them as featured.

On the subject of benchmarks, though, before Christian Guyton left for the green pastures of *TechRadar*, we spent a long time discussing our benchmark tests and how to update them. The result was our triple-build issue in July 2022, which updated our benchmarks with more games and ray-tracing tests. We're still using Cinebench to test the CPUs in our systems, just because it's such a universally well-known test, but we're open to other ideas in terms of the tests that are important to you. Email your suggestions at the address on the opposite page. ⏻

THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET

WITH A TOTAL PRICE generally around the $1,000 mark, our budget builds regularly see components changing due to sales of cheaper parts. Luckily, both builds continue this trend with our most expensive of the bunch costing just over $1,200. Kicking off with our AMD budget rig, we have a change in the motherboard. Out goes the Gigabyte B550 Aorus Elite and in comes MSI's B550M Pro-VDH. The previous board was no longer on sale and, at $125, the MSI alternative was too good to pass. Regardless of it being a Micro-ATX, it's still compatible with our components.

Prices fell slightly across the AMD machine, including on our GPU. For $15 less, we upgraded our 6650XT to ASRock's 6650 XT Challenger D OC card for some easy out-the-box overclocking. At $360, it's a brilliant budget-end GPU with more than enough power for a solid 1080p gaming experience. All other components on the AMD side remain the same, with a few price fluctuations. Overall, we saved $13 from last month—that's not much, but to have upgraded our GPU to an OC model makes it a good change.

On team Intel, most of the components are on sale or reasonably priced. One area we did swap out was the GPU. The Gigabyte Eagle OC 3060 card wasn't available at the same $330 price, so we replaced it with another GeForce RTX 3060 OC card, a 12GB MSI Ventus 3X. It's pricier, but we've gained 4GB of GDDR6 VRAM, which should allow us to bump up those sliders in games.

Unfortunately, with this slight increase in price, the overall cost of the Intel machine goes up from $1,069 to $1,122, but we do get 4GB more of gaming potential out of the graphics card. In the realms of capacity, we have stuck with the same SSD/HDD combo as previously featured. The 500GB MSI Spatium M450 PCIe 4.0 drive is still an excellent grab at $50 for your main storage solution, whereas the Seagate ST4000NM0024 7200 HDD has all the backup storage you'll need at 4TB of capacity.

AMD INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	550W Asus TUF Gaming 80+ Bronze	$49
Mobo	MSI B550M PRO-VDH WiFi AM4 **NEW**	$125
CPU	AMD Ryzen 5 5600X	$190
GPU	ASRock Radeon RX 6650 XT Challenger D OC 8GB **NEW**	$360
RAM	16GB (2 x 8GB) Corsair Vengeance LPX CL16 @ 3600MHz	$68
SSD	500GB MSI Spatium M450 PCIe 4.0 M.2 SSD	$50
HDD	4TB Seagate ST4000NM0024 7200 HDD	$70
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $1,039

INTEL INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	550W XPG Pylon 80+ Bronze	$70
Mobo	ASRock B660 Pro RS LGA 1700	$120
CPU	Intel Core i5-12600	$230
GPU	MSI GeForce RTX 3060 VENTUS 3X OC 12GB **NEW**	$380
RAM	16GB (2 x 8GB) G.Skill Ripjaws V CL16 @ 3600MHz	$75
SSD	500GB MSI Spatium M450 PCIe 4.0 M.2	$50
HDD	4TB Seagate ST4000NM0024 7200 HDD	$70
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $1,122

MID-RANGE

THIS MONTH'S MID-RANGE build is a story of price cuts, allowing you to either save money on your build or get more bang for your buck. But before we get to that, we've decided to give our mid-range case a refresh, based on the arrival of NZXT's H7 range in the labs. We have a review of the high-end H7 Elite on page 78, but the H7 Flow is the company's mid-tier offering. As the name suggests, it's built around airflow with a mesh front that allows air to pass through the system and keep it cool. We had some concerns about airflow on the higher-end model, so the H7 Flow looks like the best case to go for from this range.

Regular readers of this magazine will no doubt have noticed our excitement at graphics cards returning to normal prices, but this month, they've actually started to go below RRP. Last month, the ASRock Radeon RX 6800 XT Phantom Gaming D 16GB hit the $695 recommended price, but it's now $55 cheaper at $640. We've included that card in our AMD build for now, but we're already starting to think about the ASRock Radeon RX 6900 XT. This is the next model up and offers about 10 percent more performance. Previously, the 6900 XT has been a lot more expensive than the 6800 XT, but now it's roughly 10 percent more expensive, the performance gain is in line with the price premium, making it a no-brainer if you have the money.

On the Nvidia side in our Intel build, our RTX 3070 card has also decreased in price, although only by $20 from last issue at $560. The next model up, the RTX 3070 Ti, is $650, so that's still quite a significant step up in price for only a small performance upgrade. Otherwise, the components in our build this month have remained unchanged with little movement anywhere in the price of CPUs, RAM, or storage. New processors and GPUs are being readied, so we can look forward to some bargains at the mid-tier price level in forthcoming months.

AMD INGREDIENTS

PART			PRICE
Case	NZXT H7 Flow	NEW	$130
PSU	750W EVGA SuperNOVA 750 GT 80+ Gold		$80
Mobo	ASRock X570 Steel Legend AM4		$145
CPU	AMD Ryzen 7 5800X		$298
Cooler	Cooler Master MASTERLIQUID ML240L RGB V2		$80
GPU	ASRock Radeon RX 6800 XT Phantom Gaming D 16GB		$640
RAM	32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz		$133
SSD	500GB WD Black SN850 NVME M.2 PCIe 4.0 SSD		$85
HDD	4TB Seagate ST4000NM0024 7200		$67
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)		$32
Approximate Price:			**$1,690**

INTEL INGREDIENTS

PART			PRICE
Case	NZXT H7 Flow	NEW	$130
PSU	750W EVGA SuperNOVA 750 GA 80+ Gold		$80
Mobo	ASRock Z690 Pro RS LGA 1700		$190
CPU	Intel Core i7-12700F		$313
Cooler	Cooler Master MASTERLIQUID ML240L RGB V2		$80
GPU	MSI VENTUS 2X OC GeForce RTX 3070 8GB		$560
RAM	32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz		$138
SSD	500GB Corsair MP600 Pro LPX M.2 PCIe 4.0		$80
HDD	4TB Seagate ST4000NM0024 7200		$67
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)		$32
Approximate Price:			**$1,670**

TURBO

LAST BUT NOT LEAST, especially when it comes to performance, we have our Turbo machines. In the previous issue, we saw a few changes occurring in the Intel rig but not many over in the AMD corner. This time around we only see two changes for the Intel PC including the GPU once more and the CPU cooler. We have swapped out our MSI Gaming Trio card for Gigabytes Gaming OC 3090Ti. Purely on the basis that it was available for a lower price, it makes total sense to add it in. Plus we get the added speed benefits of this being an OC.

As for the cooler, we have saved some more cash by swapping out our previous MSI AIO for NZXT's Kraken X73 360mm cooler. We recently featured the RGB variant and this great-looking item performs efficiently to keep our temperatures low. Prices have dropped on our RAM, SSD, motherboard, and PSU, bringing our overall price tag to $3,350. That's a price drop of $157—now we can't complain about that. We have managed to upgrade our GPU further and saved some bucks in the process.

NZXT's Kraken X73 manages to sneak its way into our AMD Turbo machine too, having made a good impression. Other than this change, the other differences this time around are all monetary. Starting strong, our GPU sees a nice reduction, with $100 off the price of our ASRock Radeon RX 6950 XT OC Formula card. As with our Intel machine, the OC card comes tuned out of the box ready for even faster speeds than the standard 6950XT GPUs. With a card like this falling in price, it makes it a great addition to our AMD turbo rig.

We also see price drops on our PSU falling by $39, our RAM gets chopped by $60, and finally a $4 discount on the AMD Ryzen 9 5950X. It's not all positive news though. The ASRock X570 Taichi AM4 motherboard rises in price by $26, and we see a combined $6 rise on our SSD and HDD. Thankfully, this is nothing too crazy and our overall price tag falls by $201. On a PC with mega performance like this, that's a good result.

AMD INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190
PSU	850W EVGA SuperNova P6 80+ Platinum	$120
Mobo	ASRock X570 Taichi AM4	$250
CPU	AMD Ryzen 9 5950X	$545
Cooler	NZXT Kraken X73 73.11 CFM 360mm **NEW**	$130
GPU	ASRock OC Formula Radeon RX 6950 XT 16GB	$999
RAM	64GB (2 x 32GB) G.Skill Trident Z RGB DDR4 @ 4000MHz CL18	$280
SSD	1TB WD Black SN850 M.2 PCIe 4.0	$138
HDD	6TB WD Blue 5400 HDD	$99
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$2,783**

INTEL INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190
PSU	850W Corsair HX850 80+ Platinum	$140
Mobo	Asus TUF GAMING Z690-PLUS WIFI DDR5 LGA 1700	$260
CPU	Intel Core i9-12900K	$570
Cooler	NZXT Kraken X73 73.11 CFM 360mm **NEW**	$130
GPU	Gigabyte GeForce RTX 3090 Ti Gaming GAMING OC 24GB **NEW**	$1,400
RAM	64GB (2 x 32GB) G.Skill Ripjaws S5 DDR5 @ 5600MHz	$420
SSD	1TB ADATA XPG Gammix S70 M.2 PCIe 4.0	$109
HDD	6TB WD Blue 5400 HDD	$99
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$3,350**

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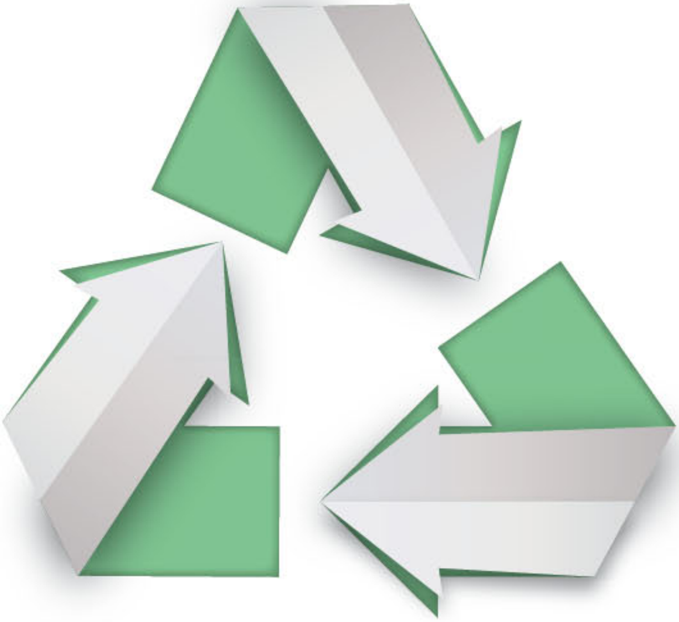

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